Illuminating Engineering

TRANSACTIONS
OF THE
ILLUMINATING ENGINEERING SOCIETY

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ILLUMINATING ENGINEERING SOCIETY
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FOREWORD.—The various topics and sub-topics are listed alphabetically. It is suggested that related or functional topics should be reviewed when one desires all references on a given subject. The issue number (1 to 9) of the TRANSACTIONS precedes the page number.

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TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XVI FEBRUARY 10, 1921 No. 1

SECTION ACTIVITIES.

NEW YORK.

Meeting—January, 1921.

The New York Section meeting of January 13 was devoted to the subject of "Removable Fixtures." Invitations had been extended to the contractor dealers, fixture manufacturers and dealers, and a large representation was present from these organizations.

The first paper of the evening was presented by Mr. O. H. Caldwell on "What the Idea Is." By recalling some of the disadvantages experienced by all in the selection of proper fixtures without an actual demonstration in the room where they were to be used, he demonstrated the desirability of such equipment.

He was followed by Mr. M. Luckiesh who read a paper entitled, "Its Relation to Better Lighting," bringing out through means of its flexibility the many advantages to be obtained under practically any conditions.

The third paper was presented by Mr. W. R. M'Coy on "The Fixture Man's Viewpoint." He laid particular stress upon the absolute necessity, if such devices were placed on the market, of there being one and only one standard type such that its application would be universal.

Mr. W. J. Shore presented the viewpoint of the electrical contractor, in a paper entitled "How it Affects the Contractor Dealer." While approaching the subject from different angles than those presented by Mr. M'Coy, he was evidently of the same opinion and he too emphasized the necessity of standardization.

The meeting was well attended, about two hundred being present.

PHILADELPHIA.

Meeting—December, 1920.

The monthly meeting of the Philadelphia Section was held in the Engineers' Club on December 17, 1920, at 8:00 P. M.

Professor C. E. Clewell opened the meeting and resigned the chair in favor of Dr. George S. Crampton.

The paper of the evening was presented by Dr. C. E. Ferree and Gertrude Rand of Bryn Mawr College, entitled, "The Effect of Variations in Intensity of Illumination on Functions of Importance to the Working Eye." This very interesting paper was accompanied by a number of slides and a great many took part in the discussion of it.

SAN FRANCISCO BAY CITIES CHAPTER.

Meeting—December, 1920.

The December 15 meeting of the San Francisco Bay Cities Chapter was held at the Engineers' Club. The subject was "The What and Why of Industrial Illumination," and the speaker, Mr. Otis L. Johnson.

Members of the following organizations attended this meeting: American Institute of Electrical Engineers, Amer-

ican Society of Mechanical Engineers, American Institute of Architects, San Francisco Chapter, A. I. A., American Association of Engineers.

Mr. Clark Baker was the speaker for the San Francisco Bay Cities Chapter, I. E. S., at the Industrial Lighting Demonstration of the Safety Exhibit of the Industrial Accident Commission in San Francisco on January 7.

CLEVELAND CHAPTER.

Meeting—December, 1920.

On December 20, at the Cleveland Engineering Society Rooms, Hotel Statler, fourteen members residing in Cleveland had a meeting to decide upon the organization most desirable for Cleveland. It was voted to form a Chapter instead of a Section.

The following officers were elected by ballot:

Chairman—J. R. Colville
Secretary—A. H. Taylor
Managers—Harry Swindell
Wm. Roy Mott
J. E. North
A. R. Holden
Ward Harrison

COUNCIL NOTES.

Upon the recommendation of the Board of Examiners, the following were elected to membership at the meeting of the Council on Dec. 9th:

Two Members.

George Rucker,
Sales Engineer,
Holophane Glass Co.,
340 Madison Ave.,
New York, N. Y.

Robert W. Stanley,
Illuminating Specialist,
Holophane Glass Co.,
340 Madison Ave.,
New York, N. Y.

Twenty Asssociate Members.

David Reeves Baker,
Production Specialist,
Electric Outlet Co., Inc.,
119 W. 40th St.,
New York, N. Y.

Eugene Braun,
Chief Electrician,
F. Ray Comstock & Morris Gest,
104 W. 39th St.,
New York, N. Y.

F. A. Coffin,
Sales Manager,
The Milwaukee Electric R. R. & Light Co.,
Public Service Bldg.,
Milwaukee, Wis.

Charles H. Crockett,
Research Engineer,
Stow Ave.,
Troy, N. Y.

Raleigh Crumbliss,
Sales Engineer,
Duplex Works of G. E. Co.,
626 McCallie Ave.,
Chattanooga, Tenn.

Thomas E. Fitzsimons,
Salesman,
Westinghouse Lamp Co.,
1008 Gas & Electric Bldg.,
Denver, Colo.

Arthur Richard Fryklund,
Sales Engineer,
Western Electric Co.,
680 Folsom St.,
San Francisco, Cal.

I. H. Gerlach,
Salesman,
Packard Sales Division, National Lamp Works,
Warren, Ohio.

Claude W. Griffen,
Efficiency Engineer,
James McCreery & Co.,
Fifth Ave. and 34th St.,
New York, N. Y.

JOHN L. HIGGINS,
Treasurer,
Electric Outlet Co., Inc.,
119 W. 40th St.,
New York, N. Y.

JOSEPH C. MILLER,
Office Manager,
L. Plaut & Co.,
432 E. 23d St.,
New York, N. Y.

A. R. MOREY,
Sales Engineer,
Duplex Ltg. Wks. of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

AL. B. NYQUIST,
Sales Engineer,
Duplex Ltg. Wks. of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

A. MORTIMER PRALL,
Salesman,
Duplex Ltg. Wks. of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

PHILIP SILVERMAN,
Traveling Salesman,
L. Plaut & Co.,
432 E. 23d St.,
New York, N. Y.

OSAKI SUE,
Chief Engineer,
% Senpakabu, Mitsai & Co.,
Kobe, Japan.

BEN TOUSLEY,
Trade Relations Representative,
Electric Outlet Co., Inc.,
119 W. 40th St.,
New York, N. Y.

A. J. WAGER,
Supt. of Power Sales,
The Milwaukee Electric Railway & Light Co.,
Public Service Bldg.,
Milwaukee, Wis.

PHILIP C. LENZ,
Duplex Ltg. Wks. of G. E. Co.,
7723 S. Park Ave.,
Chicago, Ill.

HEWITT WARBURTON,
Duplex Ltg. Wks. of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

(Subject to the Approval of the Board of Examiners.)

One Member.

CHAS. T. WILEY,
Sales Engineer,
Adams Bagnall Electric Co.,
East National Road,
Richmond, Ind.

Six Associate Members.

CONRAD BEHRENS, JR.,
Physician and Surgeon,
Specializing in Ophthalmology,
24 E. 48th St.,
New York, N. Y.

CHESTER BOOTHE BLAKEMAN,
Sales Engineer,
Duplex Ltg. Wks. of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

ADDISON H. LAWTON,
Sales Engineer,
Duplex Ltg. Wks. of G. E. Co.,
Denver, Colo.

G. A. SPAIDE,
Salesman,
Macbeth-Evans Glass Co.,
1722 Ludlow St.,
Philadelphia, Pa.

HARRY W. BUTLER,
Sales Engineer,
Duplex Ltg. Wks. of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

L. F. HECKMANN,
District Illuminating Engineer,
Westinghouse Lamp Co.,
1916 Union Bank Bldg.,
Pittsburgh, Pa.

DR. ROGERS APPOINTED ASSISTANT SECRETARY.

Dr. R. C. Rodgers has recently been appointed Assistant Secretary of the Illuminating Engineering Society. Until the time of his affiliation with the Society on January 17, 1921, he served for fifteen years in the Department of Physics of Cornell University, from which university he graduated in 1905 with the degree of M. E., and through advanced work obtained the degrees of M. A. and Ph. D.

He has been particularly interested in photometry and illumination for some years past, and while at Cornell had charge of several courses in Physics giving lecture, recitation and laboratory work. Since the retirement of Dr. Edward L. Nichols as head of the Physics Department, he has been in charge of the work in the Physics of Photography, further developing the courses originated by Prof. G. S. Moler who retired in 1917.

Dr. Rodgers is a member of the American Physical Society, the American Association for Advancement of Science, the Optical Society of America, the American Institute of Electrical Engineers, the Illuminating Engineering Society, the Cornell Engineering Society and the honorary society of Sigma Xi.

His duties with the Society will be in the direction of promoting its interests and expanding its activities and influence. He will assist the chairmen of committees, where possible, in the details of their work, and will endeavor to increase the membership of the Society.

COMMITTEE ACTIVITIES.

COMMITTEE ON AUTOMOBILE HEADLIGHTING SPECIFICATIONS.

The work of the Committee during the present administration has consisted in cooperating with the National Traffic Officers' Association, and with the Joint Committee on Uniform Vehicle Laws organized by the National Automobile Chamber of Commerce and other bodies framing propositions covering the lighting of automobiles. The results of these conferences have been satisfactory inasmuch as both bodies have signified their acceptance of the I. E. S. system for regulation. It is understood that the I. E. S. system will shortly be adopted by the State of Massachusetts.

At a meeting of the Committee held on January 5th the question of proposals to be made to a National Conference on Highway Traffic Regulations to be held in Washington during the week beginning Monday, January 10th, was discussed. It was planned for the Committee to be represented informally at this conference for the purpose of cooperating in the field in which it is concerned.

The rules and specifications put out by this Committee as revised in May, 1920, and printed as its interim report in the TRANSACTIONS (Vol. XV, No. 4, June 10, 1920) have received very extensive endorsement on the part of traffic regulatory bodies. They have been adopted verbatim by the State of Maryland and their chief provisions have been excerpted and adopted by other states. It would seem therefore that these rules and specifications, particularly in the absence of other rules and specifications in this field, are suitable for submission to the American Engineering Standards Committee for the approval of that Committee. Such approval would undoubtedly have the effect of adding considerable to the weight and to the stability of these rules, and would have the effect of promoting their wider acceptance. The Committee at its meeting on January 5th voted that

it was desirable that this should be done and that the I. E. S. Council be requested to pass a formal vote of approval of these rules and specifications and also a resolution authorizing the Committee through its Chairman to submit these rules and specifications on behalf of the Society to the American Engineering Standards Committee for the approval of that Committee.

At this meeting a discussion was also held of the apparent limitation placed on the activities of the Committee by the name given to the Committee. As a matter of fact the Committee has perforce gone beyond the field which a strict interpretation of its designation would indicate. That is, it has done more than to consider the question of specifications for headlighting. It was suggested to the Council therefore that the designation of the Committee be changed from "Committee on Automobile Headlighting Specifications" to "Committee on Motor Vehicle Lighting."

All the recommendations and suggestions of the Committee were approved and adopted by the Council at its meeting on January 13, 1921.

COMMITTEE ON PAPERS.

The Committee on Papers invites communications from members wishing to offer papers for presentation at the 1921 Convention which will probably be held in September. The Committee also desires members knowing of notable developments in the field of illumination to communicate the facts to the Committee in order that proper provision may be made for papers covering such developments.

COMMITTEE ON LIGHTING LEGISLATION.

Mr. L. B. Marks, Chairman of the Committee on Lighting Legislation, acting upon authority granted by the Council, after conference with the Secretary of the American Engineering Standards Committee, invited the following organizations to name representatives to serve on the Sectional Committee organized under the rules of procedure of the American Engineering Standards Committee for the revision of the I. E. S. Industrial Lighting Code:

SECTIONAL COMMITTEE.

Organizations	Official Representatives
Illuminating Engineering Society	(See below)
American Gas Association	W. J. Serrill
American Institute of Electrical Engineers	Prof. C. E. Clewell Dr. Louis Bell
American Society of Mechanical Engineers	Dr. A. S. McAllister
Association of Edison Illuminating Companies	G. B. Regar
Bureau of Standards	Dr. M. G. Lloyd
International Association of Industrial Accident Boards and Commissions	Thos. C. Eipper
National Electric Light Association	C. L. Law
National Safety Council	W. D. Keefer
National Workmen's Compensation Service Bureau	W. H. Cameron
U. S. Public Health Service (Department of Industrial Hygiene)	Dr. J. W. Schereschewsky

The Illuminating Engineering Society is represented on the Sectional Committee by Messrs. W. T. Blackwell, W. F. Little, R. E. Simpson, G. H. Stickney and the Chairman of the Committee on Lighting Legislation.

In connection with the proposed revision of the code the following subcommittees of the Committee on Lighting Legislation have been functioning:

Sub-Committee on Rules:

L. B. Marks, Chairman
W. T. Blackwell
Dr. M. G. Lloyd
W. J. Serrill
G. H. Stickney

Sub-Committee on Appendix:

C. E. Clewell, Chairman
C. O. Bond
Ward Harrison
S. G. Hibben
W. F. Little

Sub-Committee on Emergency Lighting:

R. E. Simpson, Chairman
Dr. Louis Bell
R. H. Maurer

The Sub-Committee on Emergency Lighting has submitted a report.

The Sub-Committee on Appendix submitted a report which has been returned for amplification.

The Sub-Committee on Rules held a meeting on Jan. 6th and devoted the entire day to a discussion of a draft of proposed revisions of the rules.

CIRCULARIZATION.

The Committee on Lighting Legislation has written to the Department of Labor in each state in which the code is not yet in force calling attention to it and offering the cooperation of the committee. The Advisory Members of the committee in the different states have also been requested to get in touch with industrial boards and legislators with a view to giving further publicity to the code. Further steps have been taken to bring this matter to the attention of legislators interested in labor laws in those states in which the Legislatures are now in session.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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Lantern and Apparatus for Testing the Light Sense and for Determining Acuity at Low Illuminations (Optician, 59, p. 243, 1920)—	C. E. Ferree and Gertrude Rand	Vol. I, No. 19	1219
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SIGNIFICANT DEVELOPMENTS IN ILLUMINATION DURING 1920.

In the *Electrical World* for January 8, 1921, appeared an article by Mr. P. S. Millar on the "Significant Development in Illumination During 1920." In this timely résumé of the important developments the author pointed out that the practice of industry to provide more effective illumination with a view to promoting efficiency is established. Reports indicate that manufacturers are convinced of its economic values, finding the small added lighting costs to be more than offset by the production economies effected.

The experimental work of C. E. Ferree and Gertrude Rand, TRANSACTIONS I. E. S., 1920, Vol. XV, pp. 769-801, partly confirming general observation and partly supplying new data, offers a scientific basis for explanation of part of the economic advantage found to result from this improvement in industrial lighting conditions.

Modes of street lighting are improving especially in designing a unit to take care of intensive lighting for evening use and for all-night service as found in the Saratoga installation.

The use of integrating spheres for the rating and tests of incandescent electric lamps is more extensive, as well as the use of the foot-candle meters for lighting inspection purposes.

The subject of reflection factors has been advanced and may now be considered cleared up. Several reflectometers have been designed or built which are capable of giving rather accurate values.

The cooperation of the reflector lamp manufacturers in adopting a standard specification for their reflectors is noted and promises to promote the field of good lighting.

A tendency towards better diffusion of light has been witnessed, large lighting units which the war-time conditions brought about are now being replaced by smaller units.

Progress in the employment of color in commercial lighting has been reported, color filters being used to bring about pleasing effects in show windows, etc.

The remodeling of old fixtures by the addition of equipment for directing and shading light sources in order to obtain good results has been tried in Chicago.

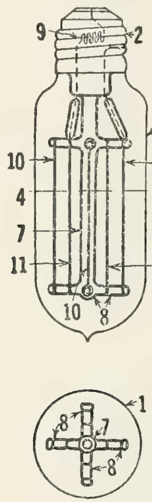
The I. E. S. Rules governing the performance of automobile headlamps on the road and specifications for laboratory tests of headlighting devices for approval by State authorities in original or revised form has been adopted by six states; and also, the same rules have been embodied in the proposed uniform traffic law of the International Traffic Officers' Association.

LOW-VOLTAGE LAMP GIVING LIGHT FROM GASEOUS CONDUCTION.

In the *Journal of the American Institute of Electrical Engineers,* for August, 1920, there was published an elaborately illustrated paper by D. McFarlan Moore entitled "Gaseous Conduction Light from Low-Voltage Circuits," in which an outline was given of the development of the types of gaseous-tube lamp of which the author was the inventor, together with a discussion of various possibilities of developing new types of lamps using gaseous conduction, and a description of a lamp that has cold electrodes and is designed to start and operate without using high potential. This lamp has as yet not been completely developed, but it seems to fulfill the conception of a gaseous-conductor lamp, without any auxiliaries, for low-potential circuits. The author expressed the hope that the great cause of new and better lighting methods in which his deep interest has been centered for years may be spurred to rapid advancement in a new direction that gives promise of reward to an unlimited number of worthy investigators and inventors.

In the new lamp, use is made of the gas neon which is unique among light sources because of its exceptional luminous efficiency. One of its remarkable properties resides in the fact that its maximum emission is

between the wave-lengths of 590 and 650. When used as a positive column of light neon gas gives a color so reddish that it would be objectionable for many purposes, but the color is yellowish when the same gas is used as a negative glow, as is done in the new lamp.



Low-Voltage Gaseous Conductor Lamp.

The lamp is shown in the accompanying illustration, taken from the application for a patent filed Nov. 30, 1917. It needs no auxiliaries for operation at 220 volts, and it will give a faint glow when operated at a voltage as low as 110. In outward form it resembles an incandescent electric lamp, and it is equally as simple, although in its present form it is far less efficient.

The central glass stem is provided with radial arms which support two windings of aluminum wires that are insulated from each other but each of which is attached to one of the two poles of the lamp base. This corona type of lamp produces a luminosity that is due not to arcing or even pure discharge phenomena but to the glowing of light emanating from electrodes or radiators that normally have a temperature below red heat.

All of the light radiated from the new type of lamp is produced by the negative discharge; not by the positive column as is the light in all of the long vacuum tubes when in operation from either a. c. or d. c. circuits. All text books and investigators have heretofore considered that the

amount of light given by the negative glow in any vacuum tube discharge was so small as to make it entirely negligible as a light source.

An ordinary long tube discharge consists of—

(*a*) next to the cathode, the short first dark space,
(*b*) the short and not bright negative glow,
(*c*) the short second dark space,
(*d*) the long brilliant positive column extending to the anode.

In the lamp just described, the positive column has been practically eliminated, and substantially the only luminous discharge in the lamp is the negative glow, which appears in the form of a velvety glow or corona of yellowish light over the entire surface of the alternating current electrodes and also a uniform gaseous radiation throughout the entire interior of the bulb. On 220 volts it uses from the line about 0.11 amp. and 21 watts, but of this amount 3.6 watts at 33 volts is consumed by a resistor 1 in. long placed in the skirt of the lamp base, thereby affording a convenient method of adjusting the wattage, life or intensity. The most important problem still to be solved is how to decrease the number of heat waves and increase the luminous radiations.

The bulb of the lamp is filled with neon gas at a pressure of 3.5 mm. Important factors in the design of this lamp are:

1—The attempt to use a gaseous conductor of maximum conductivity.
2—Electrodes that are subdivided and of as large a total area as possible.
3—A gas column (discharge gap as short as possible).
4—The plane of the electrodes of opposite polarity placed parallel to each other.
5—The length of the radiator electrodes greater than the gas column and perpendicular to it.

Cathodic disintegration is practically nil with the minimum value of cathode fall. It is greater at low gas pressures and increases with the square of the current. It appears to be due largely to occluded gases, especially hydrogen. Such gases may be removed by heating the electrodes. Bulb blackening is less with aluminum radiators than tungsten, nickel, copper, etc. Iron radiators combined with fluorescent coatings offer promise. The exceptional luminous efficiency of neon makes it unique as a luminescing medium, and it is an excellent example of selective emission. Its great scarcity until recently made progress difficult, but it can now be bought in quantity and of a high degree of purity. It is interesting to note that the negative glow is distinctly different from that of a positive column. It has no blue, violet or indigo lines and a few infra-

red rays. It is four times as good a light producer as the yellow white light of helium or the violet of xenon, both of which emit many infra-red rays.

Many different forms of lamps of this type have been produced. The chief aim must be to produce a brighter lamp. At higher voltages the production of greater candlepower is more feasible, and consequently it might be better first to develop a lamp suitable for 500-volt circuits. The brightest of the 220-volt lamps gives 2.59 spherical c. p. Some of the chief conclusions that may be drawn from results thus far obtained are as follows:

1—The efficiency of these lamps is about the same whether operating on a. c. or d. c. circuits.

2—On a. c. circuits the efficiency is the same over a wide range in voltage.

3—The efficiency also remains the same on a. c. circuits for a wide range of candlepowers.

4—The candlepower (mean spherical) varies approximately with the watts consumed on either a. c. or d. c. circuits.

5—Lamps having reasonably pure neon are not so efficient as those in which gas impurities make the color of the light whiter.

6—The performance of the lamps is not sensibly affected by wide variations in the length of the column or gap.

7—The same lamp equipped with the same resistance and operating at the same voltage takes a considerably higher line wattage on a. c. than d. c. which is doubtless due to the light radiating area being double.

8—The candlepower is greater with radiators of large area.

9—The power factor of these lamps is about 85 per cent.

When operated at 220 volts with direct current only, the negative radiator pole will give any light; the radiator wires attached to the positive pole will remain absolutely dark.

These lamps demonstrate that useful gaseous conduction light can now be produced in a simple manner from ordinary commercial circuits. The author expressed his belief that many special uses will be found for such lamps and further developments in low voltage electric gas lamps are confidently anticipated.

Much information concerning the early work connected with the development of gaseous-conductor lamps has been published in the TRANSACTIONS of the Illuminating Engineering Society, in papers by the inventor. On March 17, 1910, he presented a paper in which was described the white light from the Moore carbon dioxide tube lamp as a standard for color values, and on November 11, 1915, he presented a paper in which his lamps for color matching were described.

USE OF THE ULBRECHT SPHERE IN THE MEASUREMENT OF TRANSMISSION AND REFLECTION FACTORS.

At a recent meeting of the Optical Society of America, Dr. Enoch Karrer presented a paper on the use of the Ulbrecht sphere in the measurement of transmission and reflection factors, which will be published among the scientific papers of the Bureau of Standards.

In this paper a brief historical survey was made of the methods and instruments used in measuring the reflection factor of surfaces. The theory of the infinite luminous plane was discussed at some length in connection with the Nutting absolute reflectometer, which is based upon this theory. Recent suggestions of the use of the Ulbricht sphere were noted and several new ways of using it were described. A reflectometer based upon one of the latter ways was described in detail. This consists of a combination of the sphere with the Martens polarization photometer. The surface whose reflection factor is sought is laid over an aperture in the sphere. The brightness of it is compared with the brightness of the sphere wall. By screening the test surface from the first reflected light this comparison gives directly the unknown reflection factor. The theory of this use of the sphere was given in full. By means of this instrument the reflection factor of a block of magnesium carbonate is shown to be 98.7 per cent.

A transmissometer based upon the same theory was also described. It was also pointed out that the spectral reflection and transmission factors may be obtained in this way as a step toward the standardization of methods.

A description was also given of a simpler and less expensive reflectometer that will enable one to obtain the reflection factor of surfaces with an error not exceeding 15 per cent.

In connection with the above abstract of Dr. Karrer's paper, attention should be directed to the paper by Mr. A. H. Taylor on "A Simple Portable Instrument for Measuring Reflection and Transmission Factors in Absolute Units," which was published in the TRANSACTIONS I. E. S., Dec. 30, 1920, p. 811.

PROGRESS OF THE NATIONAL COMMITTEE FOR THE PREVENTION OF BLINDNESS.

Six years ago the National Committee for the Prevention of Blindness was organized with 65 charter members. It has grown in membership so that at the latest report there were approximately 4,000 members and donors. It has devoted itself mainly to five or six definite problems but it has also been obliged to interest itself in all phases of conservation of vision, so that its work has been concerned with a score of subjects.

Naturally, the first point of attack in all prevention of blindness movements is the prevention of loss of sight in infants, since one-fourth of all blindness in children has been found to be due to this one cause. Trachoma, wood alcohol poisoning, conservation of vision classes in schools, prevention of eye accidents in the industries are the other main subjects to which the Committee has given intensive study and has carried on active propaganda.

It has been in connection with the work for prevention of accidents in the industries that the Committee has been interested in the phase of better lighting in factories. Its handbook "Eye Accidents in the Industries," which was published in 1917, has found a large circulation and is a useful manual. Attention is called constantly in this manual to the necessity for proper lighting conditions in the prevention of accidents.

Conservation of vision classes in public schools is a movement that is not more than a half dozen years old in America but it has already proved to be a most effective means of educating children of defective sight who are not really blind.

Mrs. Winifred Hathaway, Secretary of the Committee, has prepared a manual for conservation of vision classes in the public schools which is an authority on the subject and is coming into wide use. In this manual much space is given to the subject of proper lighting in schoolrooms.

The National Committee for the Prevention of Blindness maintains an attitude of close cooperation with the Illuminating Engineering Society and depends upon it for authoritative information in the answering of inquiries peculiarly belonging to the subject of proper lighting. At the recent annual meeting of the Committee the chief topic was the relation of proper illumination in the use of the eyes, the principal address being that of Mr. H. F. J. Porter, M. E., which was entitled, "Through Life's Windows."

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XVI MARCH 21, 1921 No. 2

SECTION ACTIVITIES.

NEW ENGLAND.

Meeting—January, 1921.

A very interesting meeting of the New England Section of the Society was held Friday night, January 28, at the Engineers' Club, Boston, Mass.

Prof. William J. Drisko, Professor of Illuminating Engineering, Massachusetts Institute of Technology, Cambridge, gave a most interesting hour to "A Discussion of Reflection Factors." His remarks on "Glare Contrasts," "Shadows" and "Quality Production as Against Mass Production" were very clearly presented.

While not scheduled as one of the speakers, the Society was also honored with an impromptu talk from Past-President A. E. Kennelly, also of Massachusetts Institute of Technology. His talk was well punctuated with points of humor and proved most enlightening and entertaining.

NEW YORK.

Meeting—February, 1921.

"The Making of Colored Moving Picture Films" proved a most popular and interesting subject at the February 10th meeting of the New York Section. The paper was presented by Mr. William V. Kelley of the Prizma, Inc., who described in detail the taking of the picture and printing of the film to get the natural color values portrayed by the object to the human eye.

After the reading of the paper, motion pictures in colors were thrown upon the screen, and each phase of the development of the films was demonstrated and explained by Mr. Kelley. Red and green filters are used during the exposure when taking simultaneously the two separate pictures initially. The two films subsequently developed are so printed and dyed as to show red and green views when seen separately, but when superposed, as the films themselves are before being run in the projector, the views on the screen are shown in their proper color combinations.

He was followed by Mr. W. T. Crespinel, a photographer who had just returned from a nine months' trip to Swaziland in South Africa for the taking of colored pictures. His description of the film taken was very original, humorous and interesting. About 150 members and guests attended.

PHILADELPHIA.

Meeting—January, 1921.

A meeting of the Philadelphia Section was held on January 21st in the auditorium of the Engineers' Club. In the absence of the Chairman, Professor Clewell, Mr. G. Bertram Regar presided.

Dr. Thomas D. Cope, of the Department of Physics, University of Pennsylvania, presented a paper containing a description, illustrated by lantern slides, of the photographing by a special apparatus of the sound waves originating from the snap of an electric spark.

A second paper on "Progress in Gas Lighting" was read by Mr. Sverre Gulbrandsen of the Welsbach Company, Gloucester, N. J., who touched on the invention of the mantle, its theory as applied to performance when heated by a Bunsen flame, critical composition and weight of ash per unit surface, the relation of mantle incandesence to improvements in burners, and the improvements in burners in relation to reliable performance and adaptation to artistic housing. There was also a display of the various elements entering into composition of mantles and of various mantles, burners and complete lighting units.

Preceding the meeting a dinner was held at the Engineers' Club at which seventeen persons were present. Forty-six persons were present at the meeting.

Meeting—February, 1921.

The monthly meeting of the Philadelphia Section was held on February 18th, at 8:00 P. M., in the Engineers' Club. The first speaker was Dr. George A. Hoadley, who gave an instructive talk on "The Fundamental Requirements for the Existence of All Wave-Lengths in the Illumination of What are Called Colored Materials." In connection therewith he made clear to the layman the infinitesimal length of a wave of light, called attention to the gifts of nature in her remarkable colorings, and demonstrated the effect of the different qualities of light on colored materials.

The second subject of the evening was "A Film Presentation" by Mr. William V. Kelley, and consisted of moving pictures colored by a modern process with an explanation by Mr. Kelley of the scenes shown, and a talk by Mr. W. T. Crespinal during the showing of the film of pictures which he took on his visit to Swaziland in South Africa. This presentation was of great interest to all present.

After the meeting those present adjourned to the dining room and enjoyed a "Bit o' Sociability," in other words, conversation, coffee, and sandwiches. There were 52 present at the meeting, of whom 19 had attended the dinner preceding the meeting.

SAN FRANCISCO BAY CITIES CHAPTER.

At a meeting of the Board of Managers held on February 28, the program for the remainder of the season was formulated as follows: On March 23, Prof. B. F. Raber will present a paper on "Automobile Headlamp Lens Testing and Demonstration" at the University of California; on April 22, a Symposium on Industrial Lighting will be held at the Safety Museum, San Francisco Industrial Light Exhibit; on May 20 a visit will be made to the Oakland Mazda Lamp Factory; on June 24, the subject of "Reflectors" will be discussed at the Engineers' Club, and on September 23, at the same place, the subject of "Fixture Design" will be discussed.

COMMITTEE ACTIVITIES.

COMMITTEE ON MOTOR VEHICLE LIGHTING.

At the recent Conference on Highway Traffic Regulations held in Washington, D. C., the I. E. S. system formulated by the Committee on Headlighting Specifications (now the Committee on Motor Vehicle Lighting) was formally endorsed and recommended for adoption in the legislation of the various states. This means that there is no outstanding proposition for uniform traffic regulations which does not more or less completely endorse the I. E. S. system.

COMMITTEE ON PAPERS.

In his report to the Council, Chairman P. S. Millar stated that the work of the Committee in taking action upon papers submitted to it has proceeded without delay under the direction of Vice-Chairman Stickney. The Committee on Editing and Publication, having published in the calendar year 1920 all convention papers, advises that there is in sight at the present time material for inclusion in Part II of the TRANSACTIONS only to take care of the March issue. For subsequent issues we shall be dependent upon the technical production of Sections. The Committee repeated its general invitation printed in Part I of the TRANSACTIONS, February 10, 1921, inviting contributions for the 1921 convention program. It requested that the President appoint Mr. G. S. Merrill Chairman Papers Committee of the Cleveland Chapter, to serve on the Committee on Papers.

COMMITTEE ON REVISION OF CONSTITUTION AND BY-LAWS.

The Committee, of which Mr. W. J. Serrill is chairman, has submitted a report relating to certain revisions which have been approved by the Council for submission to the membership in accordance with the Constitution.

COMMITTEE TO CO-OPERATE WITH FIXTURE MANUFACTURERS.

A joint meeting of the I. E. S. Committee to Co-operate with Fixture Manufacturers and the Committee appointed by the National Council of Fixture Manufacturers was held in Buffalo during the week of February 14. At that time it was decided to hold a meeting of the I. E. S. Committee in Cleveland on April 12 to take definite steps toward the compilation of material which should be included in a Code of Fixture Design and Installation. It was also decided that if such a code was formulated it would be sponsored by both Committees involved.

Mr. A. S. Turner demonstrated at the Fixture Market in Buffalo the home-lighting exhibit which was kindly loaned by the Edison Lamp Works. The Committee co-operated in every way which was made possible by those in authority. About 400 persons were present at the demonstrations.

The I. E. S. Committee has assumed as its scope of activity that indicated by its name, and therefore, besides the consideration of a Code of Fixture Design and Installation, has aimed to bring about a better understanding between the designer, the manufacturer, and the dealer of fixtures, and the Illuminating Engineering Society.

NEWS ITEMS.

DR. KARRER WITH NELA RESEARCH LABORATORY.

Dr. Enoch Karrer, until recently Physicist at the Bureau of Standards, Washington, has now joined the staff of the Section of Applied Science, Nela Research Laboratory, Cleveland, where he will engage in research work. In April, 1918, as a member of the military personnel of the Army Searchlight Engineers, Dr. Karrer was detailed to work on searchlight problems in cooperation with the Bureau. After the war he entered the Bureau in a civil capacity, and was later put in charge of the Searchlight Section. During the time he was engaged in this work he carried out many valuable researches on military searchlight equipments, some of the results of which have been or will be published soon. Dr. Karrer has been a member of the Society since 1916.

WANTED—A NAME TO REPLACE "LIGHTING UNITS."

The combination, consisting of support or container, illuminant and accessories, should be designated by a name. "Lighting unit" is obviously undesirable. The word "fixture" too is unsatisfactory since it is not distinctive, applying as well to plumbing, etc. In times past such words as "candlestick," "candelabra," "lamp," have served useful purposes. There is no adequate distinction for modern combinations of the kind referred to. At a recent meeting of the New York Section of the Illuminating Engineering Society the topic of discussion was anonymously termed "removable fixtures" which illustrated the need for standardization of nomenclature in this connection.

Illuminating Engineering Society members are invited to submit suggestions for names which may be considered for possible adoption. Suggestions should be directed to the General Office and will make their appearance in due course in Part I of the TRANSACTIONS.

WESTINGHOUSE ILLUMINATING ENGINEERING BUREAU.

A new branch of technical service, the illuminating engineering bureau of the Westinghouse companies, has recently been created to assist Westinghouse interests and their field representatives in the application and sale of lamps, industrial lighting fixtures and lighting appliances. The work of the bureau will embrace the preparation of complete specifications on industrial, commercial, residential and street lighting, the preparation of technical articles and lectures, the testing and development of new accessories and the co-operative activities of engineering societies. District illuminating engineers and lighting specialists have been appointed to work with the company's lighting salesmen. Headquarters of the bureau will be located at the lamp company's works in Bloomfield, N. J., under the general supervision of the lighting service department of the lamp company. A branch will be established at the George Cutter works of the Westinghouse Electric & Manufacturing Company in South Bend, Ind., S. G. Hibben at Bloomfield will direct the general operations of the lamp company district engineers and the bureau, while C. J. Stahl in South Bend will direct the Cutter specialists.

Y. M. C. A. COURSE IN ILLUMINATING ENGINEERING.

The Central Y. M. C. A. Technical School of Chicago has announced a new evening course in illumination to cover fifteen weeks. The instructor for the course is Mr. Edwin D. Tillson, a testing engineer of the Commonwealth Edison Co., who is engaged in central station work; he is a member of the Board of Managers of the Chicago Section of the I. E. S. and is taking a very active interest in illuminating engineering.

The illuminating engineering course is prepared to benefit: (1) The lighting fixture salesman, (2) the electrical contractor and dealer, (3) the light and power solicitor, (4) the manufacturer of lamps and lighting accessories, (5) the electrical inspector, (6) the electrical maintenance man.

The course as outlined below is designed to present the facts necessary for the layout of illumination for a wide variety of purposes. It is given from the practical point of view.

SYNOPSIS OF FIFTEEN WEEKS' COURSE.

1st Week—Units of Measurement.
2nd Week—Electric Illuminants.
3rd Week—Reflectors and Enclosing Glassware.
4th Week—Diffusion of Light.

5th Week—Planning a Lighting System.
6th Week—Interior Lighting.
7th Week—(B) Schools.
8th Week—(C) Stores.
9th Week—(D) Industrial Plants.
10th Week—(E) Residences.
11th Week—Exterior Lighting.
12th Week—Street Lighting.
13th Week—Photometers.
14th Week—How to Sell Good Illumination.
15th Week—How to Sell Good Illumination (Continued).

CONTRIBUTIONS FOR THE 1921 CONVENTION.

Members who are in a position to contribute papers suitable for presentation at the annual convention which will be held probably in September or October are invited to notify the general office, advising of the subject and character of the proposed paper. It will be appreciated also if members will advise of other developments in the science or art of illumination which might with advantage be included in the program.

The character of material desired for convention presentation as set forth in the Society's Manual is as follows:

Material Desired.

1. Original contributions of new and interesting material.
2. Collections of material in new and useful forms.
3. Subjects and treatments which are peculiarly appropriate for presentation before the Illuminating Engineering Society.

Material Not Desired.

1. Material not closely related to illuminating engineering.
2. Material already available in satisfactory form.
3. Prolix treatment.
4. Papers or discussions having the manifest purpose of advertisement.

COUNCIL NOTES.

At the meeting of the Council held on February 10, the following actions were taken with reference to special committee work:

Dr. G. S. Crampton was appointed chairman of a special committee, with power to appoint additional members, the purpose of which committee is to canvass the field of ophthalmologists for new members.

It was voted to appoint a special committee to consider the matter of organizing another lecture course.

As the result of the report of the special committee appointed to investigate the business status of the Society, the following recommendations of the committee were adopted by the Council:

(1) That the Council take immediate steps to insure vigorous and effective activities calculated to increase the revenue through additional (*a*) Sustaining Memberships, (*b*) Individual Memberships, (*c*) TRANSACTIONS Sales, (*d*) Advertising Sales.

(2) That a temporary committee be appointed to report upon the Society's advertising problem.

(3) That all unnecessary illustrations in the TRANSACTIONS (especially those requiring half-tone inserts) be dispensed with.

NEW MEMBERS.

Two Sustaining Members.

ALFRED VESTER SONS, INC.,
5 Mason St.,
Providence, R. I.

L. PLAUT & COMPANY,
432-4 E. 23d St.,
New York, N. Y.

One Transfer.

DR. CONRAD BERENS, JR.,
Physician and Surgeon,
Specializing in Ophthalmology,
24 E. 48th St.,
New York, N. Y.

Three Members.

EDWIN C. ADAM,
Pres. The E. C. Adam Co.,
Lighting Fixture Manufacturers,
902 Pine St.,
St. Louis, Mo.

ALFRED W. DEVINE,
Inspector of Motor Vehicle Traffic,
R-106 State House,
Boston, Mass.

ELMAR H. WHITNEY,
District Illuminating Engineer,
Westinghouse Lamp Co.,
136 Federal St.,
Boston, Mass.

Thirteen Associate Members.

THOMAS E. BABSON,
Sales Engineer,
Sibley-Pitman Electric Corp.,
190 Sixth Ave.,
New York, N. Y.

W. H. COOK,
Architect,
1301 Mahoning Bank Bldg.,
Youngstown, Ohio.

PERCIVAL DOLMAN,
Physician-Oculist,
Pres. Council for Conservation of Vision, California,
1167 Flood Bldg.,
San Francisco, Cal.

PAUL GEORGE DETWEILER,
Manager, Illuminating Engineering and Lamp Sales Dept.,
The Hessel & Hoppen Co.,
36 Crown St.,
New Haven, Conn.

RUSSEL W. FROST,
R. W. Frost & Co.,
404 Yeon Bldg.,
Portland, Ore.

JAMES P. HARKINS,
Electrical Contractor,
Harkins & McClory,
2114 Bainbridge St.,
Philadelphia, Pa.

GEORGE A. HAUSMANN,
Electrical Engineer,
Board of Education,
6th and Rockwell Sts.,
Cleveland, Ohio.

WM. J. MCCLORY,
Electrical Contractor,
Harkins & McClory,
2114 Bainbridge St.,
Philadelphia, Pa.

CHAS. O. NYQUIST,
Sales Representative,
Duplex Ltg. Wks. of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

GERALD J. OTTESON,
Lighting Service Dept.,
Edison Lamp Works of G. E. Co.,
Harrison, N. J.

CARL W. POETER,
District Illuminating Engineer,
Westinghouse Lamp Co.,
510 W. 23d St.,
New York, N. Y.

DUDLEY W. STEEVES,
Mazda Service Inspector,
Electrical Testing Laboratories,
1648 16th St.,
Oakland, Cal.

HARVEY A. STROUD,
Electrical Engineer and Contractor,
2105 N. Eleventh St.,
Philadelphia, Pa.

ILLUMINATION INDEX.

PREPARED BY THE COMMITTEE ON PROGRESS.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

Electrical Review (U. S.)			
Illumination of Outdoor Sports—	R. E. Harrington	Jan. 15	85
Decorative Home Lighting Offers Lucrative Field—	Frank H. Miller	Jan. 15	91
Lighting Fixture Industry Ready for Buffalo Convention—		Jan. 15	95
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Longitudinal Lighting for Streets—		Dec. 2	427
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Factory Lighting Unit with Pull Switch Mounted on Shade—		Jan. 8	98
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The Lighting of Covered Lawn Tennis Courts—		Dec. 17	721
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Beleuchtung von Hallen durch Tiefstrahler—		Nov. 18	917
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Arc vs. Incandescent Lamps (Bulletin mensued de la Societe belge des Electriciens, Vol. 34, No. 4, Aug., 1920, p. 157)—	M. H. Dupont	Dec.	18a
Miners' Lamps Committee (Iron and Coal Trades Rev., Vol. 101, No. 2742, Sept. 17, 1920, p. 365)—		Dec.	22a
Furniture Worker			
Illumination of Furniture Stores and Their Show Windows—	W. H. Rademacher	Nov.	402
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Brightness of the Unclouded Sky (from Sächs. Akad. Wiss. Abhandl., Math. Phys. Klasse, 35, p. 219, 1918; Zeits. Instr., 40, p. 27, Jan., 1920)—	M. Uibe	Nov. 30	557
Stefan-Boltzmann Constant (Accad. Lincei, Atti, 28, p. 73, 1920)—	M. Kahanowicz	Nov. 30	576
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Daylight Bioscope Performances—		Jan.	87
Technical Review			
Searchlights for Military Uses (Journal of the U. S. Artillery, Oct., 1920)—	M. L. Patterson	Dec. 14	339
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Deutsche Beleuchtungstechnische Gesellschaft: 7. Jahresversammlung—		Oct.	127
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Zeitschrift fur Instrumentenkunde			
Automatische Quecksilberpumpe für hohes Vakuum mit Auffangevorrichtung für die ausgepumpten Gase (Chemiker-Ztg., 43, s. 705, 1919)—	A. Beutell and P. Oberhoffer	Oct.	203
Zeitschrift für Physik			
Uber die Einwirkung des Lichtes auf Bromsilber—	Walter Ehlers and Peter P. Koch	Bd. III, Heft 3	169

BENEFITS DERIVED FROM RESEARCH.

In order to carry out the function of stimulating industries to conduct research work, the regular meeting of the Division of Engineering of the National Research Council, Friday evening, February 4, 1921, in New York City, was largely given over to two speakers, Dr. Charles L. Reese, Chemical Director of E. I. du Pont de Nemours and Company, and Mr. A. J. Wadhams, General Superintendent of the International Nickel Company, Orford Works.

Dr. Reese brought out very strikingly the enormous advantages derived by his company from research work. The benefits from one research alone were more than sufficient to pay the expenses of the Research Laboratory for a number of years. Aside from monetary gains Dr. Reese pointed out that the research work of his company (a) resulted in increased safety of employees, (b) enabled the company to keep ahead of the art, (c) reduced selling prices of established products in spite of increased cost of labor and raw materials, (d) increased output, (e) discovered new products, the benefits of which often added to the safety, comfort and happiness of the people of the country, (f) conserved materials, (g) advanced the art in a few years equivalent to fifty years of normal experience. Disregarding those benefits which cannot be figured into dollars and cents, which are extremely important, there results to his company in a few years a saving or gain of $84,401,000 against an expenditure of $6,051,000 for research work during this period. (A profit of several times the gain quoted will eventually result from continued manufacture of these products without additional expense for research work.)

Mr. Wadhams talked on research work from an operating man's point of view. He pointed out the difficulties of the research man in the factory where all sorts of "hurdles" were placed for him to jump. In spite of these difficulties, the research man is slowly convincing the practical foreman and superintendent of the value of his work by reduced costs, increased outputs, and improvement of quality. His mission of education is not limited to this task, however, as in a great many cases it is just

as hard to capitalize the research laboratory in the eyes of the Board of Directors and convince them of the benefits derived therefrom.

At future meetings of the Division speakers from other industries will deal with the general subject of the benefits derived from research work. Executives of corporations who might advantageously be interested to follow these worthy examples, will be invited to attend these meetings.

SYSTEMS OF COLOR STANDARDS.

A paper dealing with various systems of color standards which consist of colored cards was presented by Prof. A. Ames, Jr., before the Optical Society of America, December, 1920. Five requisites which a standard of this kind must satisfy were given. They are (1) arrangement, (2) nomenclature or notation, (3) number of cards, (4) spacing, (5) standardization.

(1) The arrangement must be such that it is as easy as possible to find any desired color in the standard. The relative position of colors to one another was most clearly presented by Munsell. The best arrangement for a standard where the colors must be on a two dimensional surface, that is, a page, is to have all colors of the same hue on one page, different horizontal line designating differences in value and different vertical lines designating differences in hue.

(2) The nomenclature should be as simple as possible, should call to mind a particular color and only that color and should designate its position in the standard. Munsell's notation is believed to be the best with suggested improvements for the designation of hues.

(3) The number of cards should be sufficient so that the color of any object can be closely matched.

(4) The spacing between the cards should be the same in all parts of the standard. It should be based on the least perceptible differences. The differences between the cards should preferably be two least perceptible differences.

(5) Standardization. The color of every card should be accurately determined by colorimeter and spectral curve measurements. Every effort should be made to have the standard universally accepted so that a particular color would mean the same thing to all peoples at all times. This could be best accomplished by having the Bureau of Standards supervise the work and give it governmental approval.

Ridgway's, Munsell's, and a standard gotten out by the writer and his sister, Mrs. Oakes Ames, were considered in the paper in view of these five requirements.

Ridgway's standard, which is considered the best on the market and believed to be the one most used, fails to satisfy the first four of the requirements. It satisfies the fifth better than any other standard, but could be improved upon in this particular.

Munsell's work, it is believed, was gotten out primarily as a color atlas and notation and not as a standard to meet the requirements above mentioned. It however satisfies the requisites for arrangement and notation subject to slight improvements. The last three requisites it does not satisfy.

The Ames' standard which consists of 27 pages combining in all about 3,300 colors satisfies, subject to some marked improvements, the requisites of arrangement and notation which in general follow Munsell. Its large number of different colors causes it to meet more nearly the requisite for number than any other known standard, though a perfect standard should contain many more colors. The fourth requisite it satisfies poorly and the fifth not at all.

Before a perfect standard can be gotten out further determinations of least perceptible differences in hue (wave length) and chroma (saturation) will have to be made as there is not at present sufficient data on these differences to determine accurately the proper spacing between the colors.

The great necessity for a perfect color standard is pointed out and it is urged that immediate steps be taken to carry the work through.

DIFFUSION OF LIGHT FROM A SEARCHLAMP BEAM.

In a paper presented by Messrs. Enoch Karrer and U. M. Smith, before the Optical Society of America, which will be published among the scientific papers of the Bureau of Standards, some general considerations were given of the importance of the diffusion of the light from the searchlamp beam, and the various types of diffusion and the general characteristics of diffused light were discussed.

The distribution of brightness of the diffused light along the path of the searchlight beam was given and the amount of polarized light in this diffused light was also recorded. Some data were given to show the effect of color of the searchlamp beam and the effect of the diffused light on the visibility of targets to an observer at various distances from the searchlamps. It was pointed out how this diffused light limits the visibility and the range of searchlamps. The effects of eliminating the polarized component of the diffused light are shown not to increase the visibility but rather to decrease the visibility of targets illuminated by the beam. A comparison was made of the data on the brightness of the path of the beam with those that may be expected from the simple theory of diffusion. In very oblique directions the amount of diffused light is far greater than the simple theory would indicate. Mention was made also of the very striking phenomena of the ending of the beam and of the apparent curving of the beam. The author showed how the data on the diffused light in the searchlamp beam may be of assistance in the interpretation of certain astrophysical phenomena where it is known or believed that diffusion of light is of importance. Such phenomena are found in the luminosity of the tails of comets and in the sharp outline of the solar disk.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XVI APRIL 30, 1921 No. 3

SECTION ACTIVITIES.

NEW ENGLAND.

Meeting—March, 1921.

On March 15, at the Engineers' Club, Boston, a joint meeting of the Boston Section A. I. E. E. and the New England Section of the I. E. S. was held.

The meeting was called to order by W. I. Middleton, Chairman of the Boston Section of the A. I. E. E.

Mr. M. Luckiesh, Nela Park, Cleveland, was the speaker. His subject—"High Lights of Air Travel"—was extraordinarily interesting. It was accompanied with over 100 lantern slides, most of which were devoted to clouds, their beauties, wonders and meanings. For two hours the audience of 150 persons was transported to the aerial world and witnessed what Mr. Luckiesh very properly terms a "veritable fairyland."

At the close of the lecture a rising vote of thanks was given Mr. Luckiesh and the New England Section of the I. E. S. for the very interesting and entertaining evening.

CHICAGO.

Meetings—March, 1921.

Joint meetings of the Chicago Section and the Society of Industrial Engineers were held on the evenings of March 8th and 9th in the Lighting Demonstration Room of the Central Electric Company, 316 South Wells Street. A lecture and demonstration was given by Mr. A. L. Arenberg.

The Demonstration Room is the same as the N. E. L. A. is trying to have installed in the several cities.

Mr. J. L. Stair opened the meeting on Tuesday as Chairman, and Mr. E. D. Tillson on Wednesday. The combined attendance of these two meetings was the largest of any we have yet had. There was an attendance of 50 people on March 8th, of whom 22 were members, and on March 9th there was an attendance of 60, of whom 20 were members.

PHILADELPHIA.

Meeting—March, 1921.

The monthly meeting of the Philadelphia Section was held in the Engineers' Club, 1317 Spruce Street, on March 18, 1921, at 8:00 P. M.

The elementary talk on lighting fundamentals was given by Dr. G. S. Crampton on "The Structure of the Eye and the Fundamentals of Vision." In addition to describing the construction and functions of the various parts of the eye and illustrating the points with lantern slides, Dr. Crampton outlined and answered questions concerning defects, tests, and operations.

The main paper was "Polarization Method of Measuring Glare from Paper and Other Surfaces," by Dr. L. R. Ingersoll, of the University of Wisconsin. One type of glare is that caused by the light, directly or specularly reflected from a surface, which dazzles and impairs vision and may even work injury to the eyesight. Dr. Ingersoll, who has

developed the glarimeter for the purpose of measuring glare, demonstrated this instrument at the meeting. Looking through the lens, one is able to measure the gloss from the surface of the paper or other article to be observed. In practice this instrument enables the buyer to specify, for example, the paper he wishes, and the manufacturer, to deliver what is specified. The demonstration was most interesting.

Dr. Ingersoll explained that his investigation of this subject has been stimulated by the attention paid it by the Illuminating Engineering Society, and suggested that the Society continue this interest.

Thirty-six persons were present at the meeting, and 25 at the dinner preceding the meeting.

CLEVELAND.

Meetings—March and April, 1921.

The first open meeting of the recently organized Cleveland Chapter, I. E. S., was held in the rooms of the Electrical League on the evening of March 3d. About 150 persons were present. The speaker of the evening, Mr. M. Luckiesh, Director of Applied Science, Nela Research Laboratories, gave a very interesting lecture on "Artificial Light, Its Influence upon Civilization." The lecture, which was illustrated with slides and historical lamps, was followed with great interest by the large audience.

After the lecture a short film "Through Life's Windows," illustrating the optical principles of the eye, was shown.

An interesting series of four lectures, of which this was the first, has been arranged for this spring.

The Cleveland Chapter, at its regular meeting on April 7, was very fortunate to have as its speaker Mr. J. E. Randall, consulting engineer of the National Lamp Works, the subject of his address being "Lighting Abroad." Among other things, Mr. Randall discussed the lighting of theatres, hotels, stores, streets and railway trains in England, France and Germany. In the matter of sign-lighting he stated that there is nothing abroad to compare with such lighting as the "great white way" in New York.

Messrs. Beman, Anderson, Sturrock and Sawyer discussed Mr. Randall's paper. At the close of the discussion Mr. Swindell gave a demonstration of show-window lighting in a model show window set up in the rooms of the Electrical League. Some beautiful color effects were shown. About fifty persons were present.

SAN FRANCISCO BAY CITIES.

Meeting—March, 1921.

At the meeting of the San Francisco Bay Cities Chapter held in the Engineering Building, University of California, Berkeley, on March 23d, the following program was given: a talk on "Automobile Headlight Lens Testing," by Benedict F. Raber, Professor of Mechanical Engineering, University of California; a demonstration of headlight lens testing, by Mr. Boelter, University of California; and a paper on "The Milo-Lite Method of Glare Prevention," by Milo C. Caughrean.

NEW YORK.

Meeting—March, 1921.

The "Lighting of Common Carriers" was the subject discussed at the March 10th meeting of the New York Section. Mr. G. E. Hulse read a paper entitled "Lighting of Railway Coaches." He enumerated some of the difficulties to be overcome and explained the various systems for lighting of different types of cars, as day coaches, pullman, railway mail cars, etc. "The Lighting of Elec-

tric Railway Cars" was the title of a paper by Mr. J. A. Summers. He explained the necessity of high intensity illumination for this type of carrier, basing his assertion on the results of "speed of vision" tests. A new field in illumination was introduced by Mr. L. C. Porter and Mr. R. W. Jordan in a paper entitled "Lighting of Jitney or Motor Buses." The subject was very thoroughly covered and it was surprising to learn how much there is to what is apparently such a simple problem.

NEWS ITEMS.

Mr. Clarence J. Berry, 33, Rue Vital, Paris, France, writes that he has gone into business for himself, specializing in illuminating engineering work in France and other European countries. Mr. Berry was formerly with the firm of Brandt & Fouilleret, 23-31, rue Cavendish, Paris, and before going to France was with the National Lamp Works, Cleveland, Ohio.

Mr. Samuel G. Hibben has recently delivered several lectures in the interests of the educational work of the I. E. S., chief of which were talks before the N. Y. State Association of Contractors and Dealers, Albany, N. Y., the Fifth Industrial Safety Congress, Syracuse, N. Y., the New Jersey State Association of Electrical Contractors, Trenton, N. J., and the Stevens Institute of Technology. In cooperation with the N. E. L. A., Mr. Hibben installed and demonstrated an exhibit of Industrial Lighting at Buffalo, N. Y., during the week of February 14th and has given several demonstrations of other exhibits, such as those in New York City and Pittsburgh, Pa. A special lecture was given to the Chamber of Commerce at Pittsburgh, Pa., on March 18th and a lecture on the advantages of good lighting was given to both the Rotary Club of Allentown and to the meeting of Electrical Contractors, Jobbers and Agents in Rochester, N. Y.

NAMES SUGGESTED TO REPLACE LIGHTING UNITS.

The following terms have been suggested to the Committee on Nomenclature and Standards as suitable designations of "lighting fixture." The Committee is desirous of getting other suggestions and discussion or comment on those that have been put forward. Communications may be addressed to the Secretary of the Committee, Dr. Clayton H. Sharp, 80th Street and East End Avenue, New York, N. Y.

Illuminator
Luminaire
Luminaria
Luminure
Lumiport
Lumiduct
Luminor
Furnilume
Lighture
Fixtable
Fixable

DEFINITION WANTED FOR CENTER OF LIGHT SOURCES FOR PHOTOMETRIC PURPOSES.

It has been proposed that the Committee on Nomenclature and Standards prepare definitions of the following quantities in connection with the photometry of lamps with reflectors:

1. What shall be taken as the center of radiation of the unit: It might be the geometrical center of the filament; the geometrical center of the bulb; or the center of curvature of the mirror in the case of a parabolic reflector.

2. At what distance from the center of radiation shall the photometer be placed for (*a*) an ordinary lighting unit consisting of a lamp and shade, reflector or globe; (*b*) headlamps of the automobile and locomotive types; (*c*) flood-lighting units; (*d*) searchlighting units.
3. Apparent candlepower.

In connection with the subject of illumination the point in the unit to which the mounting height is measured should also be defined.

Communications are requested from interested parties covering these questions, such communications to be sent to the Secretary of the Committee on Nomenclature and Standards, 29 West 39th St., New York.

THE ILLUMINATING ENGINEERS SHOULD NOT MOVE.

When in the winter of 1903 the late Andrew Carnegie made his generous contribution for the erection of the Engineering Societies Building and the Engineers Club in New York City, the assumption was that the former edifice would be a temple of engineering to which all engineers might come. This it has been, to the gratification and convenience of the engineering profession. Now, however, for some reason by no means impossible to overcome, the Illuminating Engineering Society, small in numbers but not in accomplishments, is faced with the necessity of finding quarters elsewhere. This it can doubtless do without great sacrifice or cost, but this it ought not to be permitted to do. The building on West Thirty-ninth Street was erected for just such national technical societies, and certainly what little room the Illuminating Engineering Society requires can yet be found in it. Nor should the illuminating engineers be stuck in an out-of-the-way corner. They are the exponents of light, not darkness; and while they possess the skill to turn darkness into light, we presume they prefer natural illumination. If the United Engineering Society and the illuminating engineers will reason this thing out together, we are sure there will be no occasion for parting.—Editorial in the *Electrical World*, April 9, 1921.

COUNCIL NOTES.

NOMINATIONS.

At the meeting of the Council, April 14, 1921, the Committee on Nominations reported the following nominees for officers of the Illuminating Engineering Society for the ensuing year:

For President—Dr. George S. Crampton, Philadelphia.

For Vice-President—Mr. F. M. Feiker, New York.

For Treasurer—Mr. L. B. Marks, New York.

For Secretary—Mr. Clarence L. Law, New York.

For Director—Mr. A. D. Curtis, Chicago.

For Director—Mr. P. S. Millar, New York.

For Director—Prof. F. C. Caldwell, Columbus.

REMOVABLE FIXTURES.

At the meeting of the Council held on March 10, 1921, the following resolution was adopted:

WHEREAS, In the opinion of the Council of the Illuminating Engineering Socity the project for rendering lighting fixtures readily removable by the employment of suitable electric attachments as discussed at the January meeting of the New York Section of this Society, offers potentiality of large improvement in lighting conditions, and

WHEREAS, Realization of the potential value of this project is contingent upon such standardization as will make the electric attachments of fixtures completely interchangeable, and

WHEREAS, Failure to so standardize attachments would jeopardize the success of the project entailing untold inconvenience and confusion to the public, be it therefore

Resolved, That in the best interest of the public and of the lighting industry the Council hereby respectfully urge all concerned to cooperate to the fullest extent in bringing about complete interchangeability of removable lighting fixtures.

RESIDENCE LIGHTING BULLETINS.

At the April meeting of the Council it was decided to take the necessary steps to constitute a committee to be responsible for the preparation of manuscript of a bulletin on "Residence Lighting by Electricity" and a corresponding bulletin on "Residence Lighting by Gas." The personnel of this committee is to include representatives of the following interests:

- Accessory manufacturers
- Architects
- Central stations (electric and gas)
- Consulting engineers
- Contractors
- Decorators
- Fixture manufacturers
- Lamp manufacturers (electric and gas)
- Oculists.

If this bulletin attains success, it is to be made the precursor of others to be prepared by committees constituted for the purpose.

The plan of action contemplates provision by a committee constituted as above for the preparation of these two manuscripts by smaller sub-committees working either separately or jointly as may be desired, the responsibility for the plan, scope and final form of the bulletins to be assumed by the committee. Publication is of course under the Constitution to be subject to the approval of the Committee on Papers and in the hands of the Committee on Editing and Publication.

NEW MEMBERS.

Eighteen Sustaining Members.

GEORGE AINSWORTH,
576 Fifth Ave.,
New York, N. Y.

BAYLEY & SONS, INC.,
105 Vanderveer St.,
Brooklyn, N. Y.

BAUSCH & LOMB OPTICAL CO.,
635 St. Paul St.,
Rochester, N. Y.

BEARDSLEE CHANDELIER MFG. CO.,
216 S. Jefferson St.,
Chicago, Ill.

THOMAS DAY CO.,
725 Mission St.,
San Francisco, Cal.

DUPLEX LIGHTING WORKS OF GENERAL ELECTRIC CO.,
6 W. 48th St.,
New York, N. Y.

EAST SIDE METAL SPINNING CO.,
451 Greenwich St.,
New York, N. Y.

ELECTRIC OUTLET CO., INC.,
119 W. 40th St.,
New York, N. Y.

GILL BROTHERS CO.,
7th and Franklin Sts.,
Steubenville, Ohio.

ROBERT FINDLAY MFG. CO.,
224 Fifth Ave.,
New York, N. Y.

OSCAR O. FRIEDLAENDER, INC.,
40 Murray St.,
New York, N. Y.

GLEASON-TIEBOUT GLASS CO.,
99 Commercial St.,
Brooklyn, N. Y.

THE HORN & BRANNEN MFG. CO., INC.,
427 N. Broad St.,
Philadelphia, Pa.

MUTUAL LAMP MFG. CO.,
21 E. Houston St.,
New York, N. Y.

SHAPIRO & ARONSON, INC.,
20 Warren St.,
New York, N. Y.

STERLING BRONZE CO.
201 E. 12th St.,
New York, N. Y.

UNITED STATES GLASS CO.,
9th and Bingham Sts.,
Pittsburgh, Pa.

WAHLE & FRANCOIS,
201 E. 12th St.,
New York, N. Y.

Three Members.

JOSEPH F. HEFFRON,
General Manager,
Macbeth-Evans Glass Co., Ltd.,
160 Bay St.,
Toronto, Ontario, Canada.

CHARLES H. HOFRICHTER,
President,
The Crescent Brass Pro. Co.,
8410 Lake Ave.,
Cleveland, Ohio.

WHITMAN SYMMES,
President,
Thomas Day Co.,
725 Mission St.,
San Francisco, Cal.

One Transfer.

DR. PERCIVAL DOLMAN,
Oculist,
President, Council for Conservation of Vision, California,
1167 Flood Bldg.,
San Francisco, Cal.

Twelve Associate Members.

SAMUEL L. CARMEL,
Chemical Engineer,
A. C. Horn Co.,
Hancock and Bodine Sts.,
Long Island City, N. Y.

JAMES A. CAHILL,
Lighting and Power Specialist,
J. F. Buchanan & Co.,
1715 Chestnut St.,
Philadelphia, Pa.

WILLIAM P. COLLINS,
Electric Salesman,
The Collins Electric Co.,
92 State St.,
Springfield, Mass.

F. O. CREAGER,
Manager,
A. B. Products Div. National Screw & Tack Co.,
326 N. Madison St.,
Chicago, Ill.

A. E. HOLLOWAY,
Supt. Commercial Dept.,
San Diego Consolidated Gas & Electric Co.,
1327 8th St.,
Coronado, Cal.

HUMPHREY DAVY,
Electrical Engineer,
Whalen-Crosby Electric Co.,
140 N. Eleventh St.,
Philadelphia, Pa.

GUY F. KOTRBATY,
Assistant Engineer,
Interborough Rapid Transit Co.,
600 W. 59th St.,
New York, N. Y.

J. T. PERCIVAL, JR.,
Salesman,
Puget Sound Power & Light Co.,
Electric Bldg.,
Seattle, Wash.

KARL J. SCHROER,
Illuminating Engineer,
Westinghouse Lamp Co.,
111 W. Washington St.,
Chicago, Ill.

GEORGE W. SMALL,
Manager Fixture Dept.,
Interstate Electric Co.,
356 Baronne St.,
New Orleans, La.

EARL W. SMITHSON,
Sales Engineer,
Duplex Ltg. Works of G. E. Co.,
6 W. 48th St.,
New York, N. Y.

D. J. UNDERWOOD,
Wesco Supply Co.,
St. Louis, Mo.

ILLUMINATION INDEX.

PREPARED BY THE COMMITTEE ON PROGRESS.

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HENRI PIÉRON ON THE PHYSIOLOGICAL PRINCIPLES UNDERLYING THE STUDY OF LIGHT.

BY LEONARD THOMPSON TROLAND.*

Recent papers reveal in Henri Piéron, present Director of the Psycho-physiological Laboratory of the Sorbonne, a very careful student of visual problems. In a two-part article, "On the Principles Which Should Govern All Studies of Light," he offers a very comprehensive and well ordered summary of modern determinations of the relations between visual sensation and conditions of retinal stimulation. This article exhibits a remarkable conversance with American work, as well as with French, and even the Teutonic sources are not neglected. The available facts are grouped so as to support seven specific principles, from each of which practical consequences are deduced and all of which justify the single general principle that light is not an objective or physical entity, but an effect producible only through the physiological reactions of an organism. Original contributions of data by the author are limited to the problem of the laws of temporal and spatial summation of liminal stimuli, but the quality of these contributions—considered in relation to the author's enthusiastic erudition in his subject—offers hope of important additions in the future. Brief summaries of Piéron's own work are to be found in the *Comptes rendus* of the French Academy of Sciences and Society of Biology.

In his long article, above mentioned, Piéron first emphasizes the fact that light is a sensory phenomenon, resulting from the action of certain physical forces, so that its study demands a combination of physiological with physical knowledge—a union not yet achieved in France where optics is still the exclusive property of the physicists, but attained to a gratifying degree in the work of American industrial research laboratories. The first of the author's specific principles offered in support of his general thesis, states that light depends, not upon the radiant energy impinging on the cornea, but upon that which actually arrives at the sensi-

* Harvard University.

tive elements of the retina. Factors which intervene between these two stages of the process include pupillary size, the inclination of the retina to the rays, selective absorption and fluorescence of the ocular media. The work of Reeves on the pupil is reviewed. The practical consequences are that in all careful determinations of visual constants, such as the "minimum visible," pupillary size and the condition of the ocular media in the given case must be taken into consideration. Use of the artificial pupil and the reviewer's intensity unit, the "photon," is recommended.

The second specific principle states that the light intensity resulting from any given stimulus is a complicated function of five variables: (1) the total energy reaching the retinal receptors, (2) the space density, and (3) the time density of this energy, (4) the contingent retinal sensitivity, and (5) the position of the stimulus on the retinal field. The law of Bloch, which is an application of the Bunsen-Roscoe principle to the retinal process, indicates a complete summation of stimulation effects during short periods of initial excitation; but for durations longer than 0.1-0.2 seconds, the law of Blondel and Rey, $it = a + bt$, is required, and this corresponds to the law of beginning nerve excitation (Hoorweg-Weiss). However, studies by the author and others show that with very brief exposures (less than 0.002 second) the total quantity of energy required for threshold stimulation increases to a marked degree, so that there is a range of exposure times (around 0.02 second) yielding a minimum energy threshold. These temporal laws vary with the size of the stimulated area as well as with color and must be supplemented for long durations by reverse principles corresponding with fatigue. With reference to retinal sensitivity, the laws of dark adaptation must be considered. As tested by the threshold, this process apparently follows a "sigmoid" curve and may result in an increase of sensitivity by several thousand fold. The degree of adaptation exerts an influence upon the summation of stimuli within small retinal areas, which according to Ricco, Loser and Charpentier is very complete in the fovea. The work of Reeves and Piper indicates that such summation is operative, but not perfect, over areas of considerable size. This effect is modified by the position of the stimulus on the retina as well as by the state of adaptation; the persistance of vision is similarly conditioned. Dark adaptation

increases the differences between various parts of the retina. Other accessory factors influencing the response are contrast, binocular interactions, and visual oscillations. Among practical consequences of these considerations are the following: First, the laws of spatial summation imply that the apparent brightness of an object will decrease with increase in its distance from the eye, although the retinal illumination remains constant when the image is in focus on the retina. Second, with reference to photometry, direct comparisons must be made with small foveal fields, symmetrically situated with regard to the fixation point, with exposures not greatly prolonged. Third, the flicker method will yield reliable results only under carefully standardized conditions.

The third of the author's principles states that the intensity of the light generated by a mixture of radiations of different wave-lengths is a complicated function of the relative energies of the components in the mixture. The author reviews American work on visibility, with tables of approved visibility values taken from the present I. E. S. TRANSACTIONS. Unfortunately, however, the visibility curve is itself a function of retinal position, state of adaptation and the intensity of the radiant stimulus, the position of the maximum varying between limiting wave-lengths in the orange and in the blue. (In this discussion the author has apparently utilized data from arbitrary luminosity curves, rather than strict visibility values.) The facts of spatial and of temporal summation also vary with the wave-length of the stimulus, the differences for various wave-lengths depending in turn upon the position of the stimulus on the retina, etc. These influences make themselves felt in the flicker photometer and other phenomena involving persistence of vision. Consequences of these considerations are found in the Purkinje and allied phenomena. Such variations in the relative stimulating powers of different wave-lengths throw doubt on the significance of measurements made by "physical photometry"—as developed by Blondel—which assume an invariable visibility curve. Blondel proposes to employ different curves to represent day and night vision, but in fact an infinite number are required. In flicker photometry, a serious cause of error is to be found in changes in the speed of alternation of the compared stimuli, which alters their relative values on account of the differences in the laws of growth of different color

sensations. For similar reasons, at low intensities flicker photometry yields an under-estimation of the blue end of the spectrum relative to the red end, and the reverse at high intensities. In calculating the minimum visible energy, it is necessary also to take into account the differences in the laws of growth of excitation for different wave-lengths, which cause one to choose a stimulus of 490 $\mu\mu$ (instead of 550 $\mu\mu$, as taken by Buisson), with an action time of 0.003 second, a retinal image diameter of 1 μ, located 20° from the fovea.

The fourth principle formulates the so-called "duplicity" or rod-cone theory, stating that light appears to be the resultant of two receptor processes, having different wave-length response curves (visibility curves), and combining in proportions which vary with stimulus intensity, state of adaptation and position on the retina. The highly complex variations in sensitivity of the retina with changing conditions can be explained almost perfectly in terms of this theory, with its two invariable component visibility curves. (The author has again relied upon unreduced luminosity data, when he erroneously places the maximum of the cone curve at 600 $\mu\mu$). Explanation of the low intensity (rod) curve in terms of the photo-chemical reaction of the visual purple appears to be quite satisfactory, for a wide variety of animal species as well as for man. There is no visual purple and no night vision in the fovea, although there is a slight amount of dark adaptation. In night vision, an automatic change in the fixation reflex throws the fixation point off of the fovea. Von Kries estimates that the contributions of the rods and cones to vision are about equal at an illumination level between 1 and 5 meter candles (10.8 to 53.8 foot-candles). Regional differences in sensitivity in various states of adaptation are well explained in terms of the rod-cone theory, although other factors such as changes in the number of receptors connected with a single nerve fiber and the reactions of the mobile pigment cells, must be considered, especially in connection with phenomena of spatial summation.

Piéron's fifth specific principle concerns the phenomenon of color, which is a specific process depending upon wave-length for its "quality" (hue) and upon numerous other factors for its "intensity" (saturation). Color presupposes the existence of luminosity or light, but interferes seriously with evaluations of

the latter, as in heterochromatic photometry by direct comparison. The chromatic response is subject to hereditary deficiencies and may be partially or wholly inhibited by the action of certain poisons. Hue is a continuous function of wave-length. Saturation first increases and then decreases with increase in the intensity of the stimulus. In general, the sensation of hueless light is apprehended before that of hue near threshold intensities, the magnitude of the "photochromatic interval" varying widely with wave-length and retinal position. There are similar relations with time, for brief exposures. These variations are explicable in terms of the rod-cone theory, predominance of rod response being unfavorable to the perception of hue, although there is still a slight photochromatic interval even for red in the dark adapted fovea. Among consequences of the above facts are the following. In direct heterochromatic comparison, as shown by the reviewer, the brightness discrimination threshold is an elliptic function of the hue scale difference of the compared colors. The method of flicker minimizes this increase, permitting five times the accuracy of the direct comparison method. Broca and Polack have stated certain rules, based upon the relative responses of the rods and cones, for determining the colors of very faint stimuli, such as distant signal lights; and also to enable the color-blind to discriminate colors more successfully. The notion of distinct limiting fields for the perception of different colors in the retina lacks foundation, since the boundaries of these fields vary with a multitude of contingent conditions.

The sixth specific principle deals with color mixture, and states that in a group of heterogeneous radiations, color is a function of the relative intensities of the various constituents and is completely annulled for certain intensity distributions. For many combinations of wave-lengths the resulting hue is that of an intermediate wave-length, but with certain critical combinations (complementaries) the hue entirely disappears. Hue acts like a "salient" emerging from luminosity, its "intensity" (saturation) depending upon the relation between the energy arousing the chromatic process and the total energy arousing the luminous response. The facts of dichromatic (color-blind) vision indicate that the chromatic response can be attributed to the action of two double processes, each of which produces two colors by

mutually antagonistic mechanisms. Consequences of the above considerations include the following. Chromatic response is a secondary, not a fundamental characteristic of vision, a fact strongly indicated by evolutionary as well as general physiological data. The views of Helmholtz on the relations of chromatic and achromatic vision are therefore in error. Color vision provides us with a rough index of the spectral constitution of visual stimuli.

Piéron's seventh and last principle affirms that in spite of our detailed knowledge of the conditions controlling the visual process, the magnitude of accidental variations, between individuals and in a single individual from time to time, makes it impossible rigorously to deduce the intensity of the visual effect from the given conditions of stimulation. Only the responses of the *average* individual, an ideal being, can actually be computed. There are not only variations in the forms of the two component visibility curves, but also in the ratio of participation of the two processes. The investigations of Crittenden and Richtmyer show that a considerable number of individuals are quite unfit for heterochromatic photometry.

All of the above principles show how "imprudent" it is to include the study of light among the problems of *physical* science. The physicist should confine himself to the investigation of radiant energy, but the psychophysiologist, whose function it is to study light in itself, must not neglect to keep in touch with the findings of physics.

M. Piéron's original researches in physiological optics, as indicated by the titles in the appended bibliography, have been concerned mainly with the laws of temporal and spatial summation of brief or faint visual stimuli. His studies in this field were begun before the war, by which they were interrupted, and it is indeed fortunate in view of their admirable method that the interruption was only temporary. Some of his most important earlier work was concerned with the psychophysiology of memory, or the phenomena of neural retention, in lower animals as well as in man. His conversance with physiological conceptions and methods is apparently on a par with his psychological and physical erudition and his ability to handle all problems in a clear, quantitative fashion. M. Piéron is at present editor of *L'annee psychologique*.

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TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XVI — JUNE 10, 1921 — No. 4

SECTION ACTIVITIES.

PHILADELPHIA

Meeting—April, 1921.

The monthly meeting of the Philadelphia Section was held in the Engineers' Club, 1317 Spruce Street, on April 22nd, 1921, at 8:00. In the absence of Chairman C. E. Clewell, Dr. G. S. Crampton presided.

Mr. Davis H. Tuck of the Holophane Glass Company, in a five minute talk, described and exhibited the "Lightmeter."

The first speaker was Mr. Earl A. Anderson of the Engineering Department, National Lamp Works, Cleveland, Ohio, who addressed the meeting on the "Fundamentals of Illuminating Engineering and Methods of Calculation." This talk was based on Bulletin 41, Illumination Design Data, recently issued by the National Lamp Works. This bulletin contains information to enable one to design a lighting system by following out some simple rules which are given in detail. Mr. Anderson's talk was of great interest to persons wishing to design lighting systems without consulting experts or making difficult observations and calculations.

The main paper of the evening was presented by Mr. J. L. Minick, assistant engineer, Pennsylvania Railroad, Altoona, Pa., on "Developments in the Lighting of Engine Houses." Mr. Minick explained how the periodic increases in the size of the locomotive had affected the design of engine houses and likewise of the lighting systems therein. The atmosphere in an engine house contains so much moisture and dirt as to make the maintenance of the lamps a most important feature. Lantern slides were used effectively in the explanation of these points.

At the meeting were present thirty-nine persons, and at the dinner preceding the meeting twenty persons.

CLEVELAND

Meeting—May, 1921.

A very interesting and instructive meeting of the Cleveland Chapter was held on May 12, the speaker being Mr. Earl A. Anderson of the National Lamp Works. Mr. Anderson's subject was "Fundamentals of Light Control." By the use of many well-arranged experiments and exhibits the speaker described and illustrated the fundamental principles upon which the modern systems of light control embodied in reflectors, refractors, etc., are based. His talk was followed by an interesting discussion. The audience, which included representatives from many diversified interests, numbered about fifty.

This was the third of a series of talks which have been arranged by the Cleveland Chapter. They have been planned

with a view to interesting persons in many lines of work. All have been well attended, and it is believed that plans which are now under consideration for further meetings will materially add to the support which the Chapter is receiving in Cleveland.

MILWAUKEE

Meeting—May, 1921.

The monthly meeting of the Engineers Society of Milwaukee was held on May 18, at the Milwaukee Athletic Club, under the auspices of the Illuminating Engineering Society, Mr. F. A. Vaughn, Local Representative of the I. E. S., presiding.

Mr. Lionel Robertson, Art Director of the Tobey Furniture Company, Chicago, gave a demonstration-talk on "The Lighting of the Home." He described the lighting of the home-premises, starting on the exterior and proceeding up the drive, through the entrance and veranda, to the different rooms in the house, describing each specifically. Many interesting demonstrations showing the effect of colored lights upon the hangings, wall-paper and furnishings were given. Combinations of different color-schemes were also illustrated by means of table-lamps, floor-lamps, wall-paper and fabrics.

Mr. Robertson's cooperation in accepting the Illuminating Engineering Society's invitation to talk in Milwaukee was much appreciated, as was evidenced by the intense interest maintained by the audience and the lively discussion which followed. Unusual meetings of this character are far-reaching in their effect on the public. Local architects and contractors who wire and equip homes with electric-light fixtures were invited, and an audience of approximately 150 was present.

SAN FRANCISCO BAY CITIES

Meeting—April, 1921.

A meeting of the San Francisco Bay Cities Chapter was held on April 22, 1921, at 8:00 P. M. at the Safety Museum, Industrial Accident Commission, 529 Market Street, San Francisco, California.

Previous to the meeting Mr. H. H. Millar, Electrical Testing Laboratories, delivered the Industrial Lighting Demonstration Lecture. After the lecture, the meeting was called to order by Chairman L. E. Voyer, who called upon Mr. J. R. Cravath, consulting engineer, to talk upon "The Objects and Aims of the I. E. S."

Mr. Cravath told what the I. E. S. had accomplished in the past and what it is now trying to do, and outlined the classes of men who should be members of the Society. He mentioned the fact that the Transactions alone are worth more than the dues.

Mr Voyer next called on Mr. Clark Baker, who spoke on "A Survey of Lighting Conditions in Industrial Plants." Mr. Baker is with the National Lamp Works of the General Electric Company and the Survey was made for this company.

Mr. Robert Eltringham, Manager, California Electrical Cooperative Campaign, discussed the Industrial Lighting Demonstration, calling attention to the ease with which a lighting installation may be designed.

There was a total attendance of twenty-two, ten of whom were guests.

TORONTO

Meetings—April and May, 1921.

Members of the Illuminating Engineering Society resident in Toronto, met in the Club Rooms of the Toronto Hydro-Electric Club, April 25, 1921, for

the purpose of forming a chapter of the Illuminating Engineering Society in Toronto.

Mr. W. P. Dobson, who presided, advised the gathering of the objects of the Society, and the rules governing the formation of a chapter of the Society, where the membership is not sufficient to form a regular section.

The meeting decided to organize a chapter as provided for in the Constitution of the Illuminating Engineering Society, to be known as the Toronto Chapter of the Illuminating Engineering Society.. Officers and executive committee were elected as follows: President, Mr. Geo. Cousins; Secretary-Treasurer, Mr. W. H. Woods; Prof. G. R. Anderson, and Messrs. M. B. Hastings and Frank K. Groome..

Considerable interest was manifested at the organization meeting and on Friday, April 29th, a joint meeting was held with the American Institute of Electrical Engineers at which Mr. D'arcy Ryan, of the General Electric Company, delivered an illustrated lecture on Illuminating Engineering which was attended by approximately 425 people.

The Toronto Chapter held its first general meeting after organization in the assembly room of the Engineers Club, 96 King St., W., on the evening of Wednesday, May 18. The Executive Committee cooperated in the preparation of an interesting illustrated paper on "Store and Window Lighting" to be presented by Mr. Frank K. Groome.

NEWS ITEMS.

At a meeting of the Committee on Nomenclature and Standards, May 19, 1921, the matter of a generic term for "lighting unit" was considered. The suggested name "luminaire" was deemed to be the most acceptable one which had come to the attention of the Committee. The Committee, while tentatively recommending the use of this term, expressed its wish that it might receive criticisms and further suggestions.

STANDARDIZATION OF OUTLETS

It is understood that a large number of manufacturers interested in equipments for "Removable Fixtures" are in agreement that all such fixtures should be inter-changeable, and to that end have practically agreed upon a design or designs which will accomplish this purpose. In these designs the means for mechanical support of fixtures are independent of the current-carrying parts.

POPULAR EDUCATION ON ILLUMINATION

As summarized in the April 30, 1921 TRANSACTIONS of the Society, Mr. Samuel G. Hibben, chairman of the sub-committee on popular education of the I. E. S. committee on education, has given several lectures in the interests of the educational work of the Society. Some of the work on popular education has been dove-tailed with the N. E. L. A. Industrial Lighting Exhibits, and the chairman has devoted considerable time assisting in the installation or demonstration of such exhibits at Buffalo, N. Y.; Pittsburgh, Pa.; New York, N. Y.; Rochester, N. Y.; St. Louis, Mo.; and Kansas City, Kan. Lectures on the advantage of better lighting, particularly covering industrial illumination have been given to the Rotary Club of Allentown and of Reading, Pa.; to the Electrical Contractors, Rochester, N. Y.; to the Association of Public Utilities, Kansas City, Kansas; and to the Central Mississippi Valley Safety Congress, St. Louis, Mo. Work is being continued to

assemble sufficient number of lantern slides for several popular lectures, and to date about fifty such slides have been secured.

The committee will cooperate with the newly appointed committee of the I. E. S., to draft semi-technical or general lighting bulletins, to be printed by the Society and issued to schools, colleges, etc., to cover the field and in a measure replace the various engineering bulletins now being distributed by several manufacturers.

RESEARCH IN PHYSIOLOGICAL OPTICS

Under the auspices of the Division of Physical Sciences of the National Research Council, there has recently been formed a Committee on Physiological Optics consisting of:

- Prof. Adelbert Ames, Dartmouth College
- Prof. W. T. Bovie, Harvard University
- Dr. P. W. Cobb, Nela Research Laboratory
- Mr. L. A. Jones, Eastman Kodak Company
- Dr. W. B. Lancaster, Boston
- Dr. P. G. Nutting, Pittsburgh
- Dr. I. G. Priest, Bureau of Standards
- Prof. J. P. C. Southall, Columbia University
- Dr. L. T. Troland, Harvard University
- Prof. F. K. Richtmyer, Cornell University

with the last named as chairman.

This committee recently held a meeting in New York for the purpose of organization and discussion of the problems before it. The diversity of present theories of vision was thought to be due in large part to the circumstance that the workers in the sciences contributory to visual phenomena. such as physics, physiology and psychology, seldom, if ever, get together to talk over problems of mutual interest and to learn of each other's viewpoint.

To facilitate an interchange of ideas among the various groups of workers, the Committee voted to request the Optical Society of America to form a Section on Vision. Such a section has been authorized by the Society and the first meeting will be held in Rochester in October, 1921. It is hoped that all those interested in the pure or applied science of Vision, such as physicists, physiologists, psychologists, ophthalmologists photochemists, illuminating engineers, etc., will join the new Section and will take an active part in its work.

The committe will also immediately make a survey of present research in progress. Later there will be issued a report on the present status of Physiological Optics with some outstanding problems for research.

NELA LIGHTING HANDBOOKS

The Handbook Committee of the National Electric Light Association, has just announced the publication of two handbooks—one on Industrial Lighting and the other on Lamp Equipment for Commercial and Industrial Lighting. These books are especially written for commercial men, and embody an interpretation of the principles promoted by the Illuminating Enginering Society. In fact, most of the committeemen, who prepared the books, are active members of the Society. The treatise on industrial lighting presents a popular exposition on the whys and wherefores of modern practice—why good illumination should be sold and how it can be secured to meet various requirements.

The lamp equipment book is a comprehensive index of the principal types

of light-modifying equipment for use with incandescent lamps in commercial and industrial lighting practice. Full data on the light performance, including illustrations and photometric curves are giyen, as are also constants for estimating the illumination produced. Equipments are cross-indexed with a list of applications according to building conditions and use of light. They are also cross-indexed with a list of equipment manufacturers. These facilitate the proper selection and application of equipment, so that it is easier to assure a good lighting result.

The books, which are neatly bound in flexible card covers—size 4 by 7 in., are obtainable at the cost of printing and distributing—namely, fifty cents per copy—from the general office of the National Electric Light Association, at 29 West 39th Street, New York City.

DR. KENNELLEY AS EXCHANGE PROFESSOR

Dr. A. E. Kennelly, past-president of the Illuminating Engineering Society, professor of electrical engineering at Harvard University and the Massachusetts Institute of Technology, has been selected as the representative of a group of seven American universities which have established a joint exchange of professors in engineering and applied science with the French University Administration. The seven cooperating institutions are Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, Pennsylvania and Yale. Dr. Kennelly sailed from New York on June 9.

MR. FEIKER TO AID MR. HOOVER

Mr. F. M. Feiker, formerly chairman of the New York Section of the Illuminating Engineering Society and recently nominated as a vice-president of the Society for New York, has been appointed by Secretary Herbert Hoover as his personal assistant in the development of the Department of Commerce as an aid to industry. Mr. Feiker, who is a graduate of the Worcester Polytechnic Institute, class of 1904, was for several years chairman of the editorial board of the A. W. Shaw Publications of Chicago, and is now vice-president and chairman of the editorial board of the McGraw-Hill Company, Inc., of New York, publishers of engineering and industrial periodicals. He will assist Mr. Hoover in the development of the statistical and research branches of the Government in such a way as to provide information and help for the needs of the average business man and the small manufacturer, who have neither the opportunity, nor the capital, to make the necesary investment individually to make this possible.

DR. ROSA DIES SUDDENLY

Dr. Edward B. Rosa, who has served as a director of the Illuminating Enginering Society, as chairman of its Research Committee and member of its Committees on Papers and Nomenclature and Standards, died suddenly in his office at the Bureau of Standards, Washington, on May 17, 1921. Dr. Rosa has done notable work in the scientific field, and particularly in electrical research. He was born in Rogersville, New York, Oct. 4, 1861. After graduating from Wesleyan University, Middletown, Conn. in 1886, he entered Johns Hopkins University, Baltimore, and received the degree of Doctor of Philosophy. Serving for short periods as instructor at the University of Wisconsin and as Professor of Physics at Wesleyan he became the chief physicist of the Bureau of Standards in 1901.

One of his first achievements was to

develop the physical side of the respiration calorimeter with Professor W. O. Atwater at Wesleyan. This apparatus was of great value in the pioneer investigations of the value of foods. With Dr. Dorsey as collaborator Dr. Rosa in 1907 began work on the determination of the ampere which has been perfected until it is now possible to define the ampere in a satisfactory manner. With Dr. Grover he collected practically all the known formulæ for computing inductions. This collection is known throughout the world as a model.

Another achievement was to establish definitely the laws governing electrolytic corrosion, a problem of major importance to public utility companies, particularly those operating underground gas and water pipes and electric railways. In the World War, Dr. Rosa developed a number of scientific instruments of great value to the American forces in France. Among these was a sound ranging device for locating big guns, the geophone for detecting mining operations, the development of aircraft radio apparatus and the improvement of radio direction finders by which enemy ships and aircraft could be located. Under his direction the Bureau of Standards has established what is perhaps the finest radio research laboratory in the country. Dr. Rosa also perfected devices to insure safety devices in industrial plants. In addition to his committee work for the Illuminating Engineering Society, Dr. Rosa has served as a member of the Standards Committee on the American Institute of Electrical Engineers and has been a very active worker for the American Engineering Standards Committee. At the time of his death he was one of the official representatives of the Illuminating Engineering Society on the Governing Board of the American Association for the Advancement of Science; a Fellow of the American Institute of Electrical Engineers; a member of the U. S. National Committee on the International Electrotechnical Commission; a member of the main Committee of American Engineering Standards Committee as a representative of the U. S. Department of Commerce and a member of the Executive Committee; chairman of the Rules Committee and chairman of the National Safety Code Committee of the A. E. S. C. In addition to the organizations just named he was a member of the National Academy of Sciences, American Philosophical Society, American Association for the Advancement of Science, the American Physical Society, the Societe Francaise de Physique, the Washington Academy of Sciences, the Philosophical Society of Washington, and was secretary of the Internation Committee on Electrical Units and Standards. He has been the recipient of the Elliot Cresson medal of the Franklin Institute.

At the meeting of the I. E. S. Committee on Nomenclature and Standards on May 19th, the following resolution was passed:

RESOLVED: That this Committee desires to express its great sense of loss in the sudden and unexpected death of Dr. Rosa who has done so much in the past to aid the cause of illuminating engineering. The members of the Committee desire to offer their personal condolence to the Bureau of Standards and to Dr. Rosa's family.

THE SOCIETY'S HEADQUARTERS

As will have been noted from the April issue of the I. E. S. TRANSACTIONS, the *Electrical World* called attention editorially on April 9, 1921 to the fact that the Illuminating Engineering Society was then confronted with the problem of finding quarters outside of the Engineering Societies Building, New York, which had served as headquarters of the society since the building was erected.

It is gratifying to state that the Illuminating Engineering Society will continue to have its headquarters in the Engineering Societies' Building, as satisfactory arrangements have been made with the United Engineering Society, which offered the I. E. S. space on the sixteenth floor of the building, and this was accepted by the action of the Council on June 9, 1921. The arrangement of the new offices and other details were left in the hands of the General Secretary by the Council.

THE DELAY IN PRINTING

Most of our members have read in the daily press of the printers' strike which was called on May 1st, which strike has been the cause for the tardy publication of the present issue.

We were advised late in April by the printers of the I. E. S. TRANSACTIONS, the Chemical Publishing Company, Easton, Pa., that the strike would be called and even as this issue is being sent to press the strike has not been settled.

However, the Chemical Publishing Company has recruited a new force of printers, and we have succeeded in publishing this issue largely with material already in type. Doubtless these facts will be given due consideration by our members, and proper allowance will be made for any shortcomings.

The July 20th issue is now being prepared for the press and the Committee on Editing and Publication expect that it will be ready for the mail in the near future.

Every effort will be made to get the August 30th issue out on time.

With this explanation it is hoped that all of our members and subscribers will be satisfied.

NEW OFFICERS

At the June Meeting of the Council the report of the Committee of Tellers was read and accepted. According to the returns reported by the committee the following have been elected to the offices indicated:

General Officers

President

Dr. George S. Crampton

General Secretary

Clarence L. Law

Treasurer

Louis B. Marks

Vice-President

Frederick M. Feiker

Directors

A. D. Curtis

F. C. Caldwell

P. S. Millar

NEW YORK SECTION

Chairman

H. V. Bozell

Secretary
S. W. Van Rensselaer

Managers
Herman Plaut
S. G. Hibben
E. A. Mills
Davis H. Tuck
John Doyle

New England Section

Chairman
Wm. J. Drisko

Secretary
J. T. Kerens

Managers
J. W. Cowles
F. A. Gallegher, Jr.
John Nash Ives
Edwin S. Parker
E. E. Stevens

Philadelphia Section

Chairman
H. B. Andersen

Secretary
H. Calvert

Managers
J. R. Henry
Howard Lyon
W. L. Nodell
Emile G. Perrot
G. Bertram Regar

Chicago Section

Chairman
F. F. Fowle

Secretary
Albert L. Arenberg

Managers
Albert Scheible
F. A. Rogers
J. J. Kirk
Lee Farmer
J. H. Allen

NEW MEMBERS

Five Members

Richard C. Heather,
President,
R. C. Heather Co.,
19. W. 36th St.,
New York, N. Y.

Claude B. Hellman,
Lighting Fixture Dealer,
Claude B. Hellman Company,
403 N. Charles Street,
Baltimore, Md.

Harry S. Rainsford,
Vice-President,
R. C. Heather Co.,
19. W. 36th St.,
New York, N. Y.

L. M. Sperry,
Manufacturers Agent-Manager,
917 Pine Street,
St. Louis, Mo.

P. Schuyler Van Bloem,
President,
Viking Sign Co., Inc.,
Viking Advertising Corp.,
617 Eighth Ave.,
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TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XVI JULY 20, 1921 No. 5

SECTION ACTIVITIES.

CHICAGO.

Meeting—May, 1921.

The May meeting of the Chicago Section was held at the Tobey Furniture Company, N. Wabash Ave. Mr. Lionel Robertson, Art Director of the Tobey Furniture Company, presented a paper on "Home Lighting."

About sixty members and guests were present at the meeting.

CLEVELAND.

Meeting—June, 1921.

The June meeting of the Cleveland Chapter was held in the Laboratory of Applied Science, Nela Research Laboratory on June 16th. Mr. M. Luckiesh, Director of Applied Science, gave a very interesting and instructive lecture on the subject of "Lighting the Home." This subject has been brought to the forefront recently in Cleveland by means of a modern electricial home which was open to the public for a month. Mr. Luckiesh who planned the wiring and lighting of that home, discussed it in his talk

Two demonstration rooms in the Laboratory were inspected by the visitors. In one of these rooms are demonstrated in a very comprehensive manner some of the possibilities in home lighting. In the other some interesting applications of color in lighting are shown.

The lecture and demonstrations were attended by a mixed audience of about eighty.

PHILADELPHIA.

Meeting—May, 1921.

Instead of the usual more or less steriotyped monthly meeting in which the various phases of lighting such as that of factories, churches, schools and city streets are dwelt upon, the Philadelphia Section at its meeting on May 20th blazed a new trail in having for its general theme the illumination of man himself. It is probable that few of the non medical part of the audience had ever suspected that man had so many nooks and crannies in his anatomy that it was necessary to illuminate for purposes of diagnosis and study, and the medical and dental part of the audience had probably never seen gathered together at one time such an array of special illuminated instruments as were shown by the speakers of the evening.

There were lamps for spot, flood, penetrating, indirect and constrast lighting. None of our usual methods of lighting seemed to have been overlooked, and to it all was added the X ray. To enumerate the parts illuminated would be to write a miniature hand book of anatomy including terms seldom if ever met with by the illuminating engineer.

Dr. Curtis C. Eves demonstrated upon a patient, who happened to be his coworker Dr. Hughes, the transillumination of the cavities of the head. As Dr.

Eves expressed it his friend had that morning fortunately developed an infection of his antrum. The differences in shadow density in the opposite sides of the face could be readily seen when comparison lights were properly adjusted with the rheostat.

Dr. George M. Coates spoke on "The Illumination of the Cavities of the Head for Diagnostic Purposes." Most ingenious periscope like instruments were shown and demonstrated upon another willing victim.

Dr. George S. Crampton whose subject was "Ancient and Modern Use of Light in the Study of the Eye" showed a model of the original opthalmoscope invented by Von Helmholtz in 1851 as well as a number of the latest instruments for the examination of the interior of the eye, some of which were of highly technical construction.

Present day illuminating engineers may be interested in the following short quotation from Dr. Crampton's paper in which he referred to Von Helmholtz. "It is most fitting that this gathering of those interested in the science of illumination should hear the story of one of the greatest illuminating engineers in history, although the designation 'illuminating engineer' was not even in use in his time.

"Since his day much thought and study have been centered on the skillful illumination of buildings, both palacial and plain, but never has a chamber been successfully illuminated in all the ages that equaled in importance to the human race the illumination of that wonder palace of vision, the human eye.

"Imagine the tumult of emotions that surged through the brain of that greatest of illuminating engineers when his researches were rewarded, and he saw for the first time in all its glory the interior of that small round room, the crimson tapestries of which are the very elements of the brain itself. He saw a fairy canopy suspended from the sun like optic nerve by cords of living coursing blood.

"Von Helmholtz who lived to be honored by the entire civilized world for the invention of the opthalmoscope was a blood descendent of our William Penn.

"Up to his time it was considered impossible to penetrate the dark pupillary depths of the human eye for purposes of study, although glimpses had been had of the fiery glow from the eyes of certain animals even in Pliny's day. It remained for Von Helmholtz to discover that light entering the eye reflected back exactly along the path over which it had passed and that if one was to see the interior of the eye he must place his own pupil in the path of the emerging rays. This had always been the difficulty, as in so doing one shut out most of the direct entering rays and saw nothing but a darkened chamber.

" However, in his opthalmoscope he adjusted a pack of thin glass plates in such a manner as to throw the light reflected from their sufaces into the pupil, while at the same time his own eye was in a position to catch the returning rays as they passed through the plates."

Owing to illness in his family Dr. Chevalier Jackson was prevented from demonstrating his methods of examining the interior of the bronchi and esophagus but this was skilfully done by Dr. Coates who also showed lantern slides of X-rays of the lungs of persons who had mislaid such things as safety pins, tacks, sections of small lead pipe etc., in their bronchial tubes. After each picture he stated the number of minutes and seconds it had taken Dr. Jackson by means of the bronchoscope to see

the object pass into the lungs, and remove it.

Dr. Alexander Randall showed many clever instruments for the examination of the bladder, probably the most unique being one for photographing the interior of that organ. By means of another instrument, delicate tubes of waterproofed silk could be guided, under observation, into the orifices of the ureters through which the kidneys pour their secretion into the bladder.

Dr. Dudley Guilford spoke on "The Illumination of the Dental Operating Room and Oral Cavity" and Dr. Charles F. Mitchell on "Illumination of the Operating Table from the Standpoint of the General Surgeon."

Mr. Davis H. Tuck of the Holophane Company covered the subject of "The Lighting of Operating Rooms in Hospitals."

During the afternoon an exhibition of the various illuminated instruments used by physicians and dentists was held in the oak room of the roof garden and preceeding the meeting the members and their guests dined in the adjoining South Garden.

More than 3000 members of the medical and dental profession were invited, and the large audience seemed to enjoy the noval entertainment.

Meeting—June, 1921.

In June the Philadelphia Section combined with the Phildelphia Sections of the A. S. M. E. and the A. I. E. E. in an outing at McCall Field, which proved to be a very enjoyable occasion.

NEW ENGLAND.

Meeting—April, 1921.

The April meeting of the New England Section was held at the Engineers' Club, on April 21, 1921.

A paper on "The Knowns and Unknowns in Illumination" was presented By Mr. E. Leavenworth Elliott, of the Cooper Hewitt Electric Co., Hoboken, N. Y. About 45 members were present.

Continuing its instructive course of lectures on various phases of light and illumination the New England Section held a session on June 24th in the Jefferson physicial laboratory at Harvard for the purpose of being addressed by Professor E. L. Chaffee on visible and invisible light. As the speaker developed his subjects in an informal way, by the aid of charts, pictures, projections and light rays the occasion assumed the nature of an entertainment as much as of instruction. N. W. Gifford, chairman of the section, presided.

Professor Chaffee demonstrated how easy it is to camouflage by the manipulation of colors, since it is in the nature of colors to reflect certain color rays and conceal others. In one of these demonstrations he focused a ray of light upon large pasteboard and the letters "H. U." were seen on the board, and when he filtered the ray through another plate which changed the color the "H. U." vanished and the letters "Phy. Lab." appeared in their place. Both these groups of letters had been painted on the pasteboard, but they could be concealed or made visible by the use of the light. Similarly one stream of light gave the impression that the paper suspended in the air was pure white, but when another ray was focused on it the picture of a horse that had been painted on the paper became visible while still another light gave visibility only to the paint that outlined the skeleton of the horse. These principles were applied by the camouflage divisions in the World War to conceal the identity of airplanes, searchlights

subduing some of the colors and giving reality to other designs that otherwise were invisible.

Problems of this type were demonstrated and discussed for more than an hour, bringing out many principles that were new and interesting to the audience.

NEW YORK.

Meeting—April, 1921.

At the April 14th meeting of the New York Section the subject "Use of Light in the Surgical, Dental and Opthalmological Professions" was discussed.

Dr. Louisa P. Tingley read a paper treating of the methods of illumination used in these fields, based largely on the replies to a number of questionnaires she had sent out. The subject was treated in detail and evidenced considerable work and research on the part of Dr. Tingley.

"The Lighting of Hospitals and Operating Rooms" was covered by Mr. Davis H. Tuck. He found through investigation of a number of installations that the problem in this case parallelles that of industrial lighting, in that the results to be obtained are identical in the fundamental requirements. He expressed the belief that a general higher intensity of illumination from indirect sources is the most desirable method.

"The Lighting of Electro Surgical Instruments" was reviewed by Dr. Thorvald Maijgren, who mentioned some of the more important developments accomplished in this line since 1898. He expressed the opinion that the principal progress in the future would be accomplished in the way of transillumination through stronger light with greater penetration into the various tissues of the living body. He closed with the statement. "I wish to assert that in all human history no lamp ever invented has contributed so much to the welfare of the race; has done so much to alleviate suffering and preserve human life as the surgical lamp."

Dr. Percy Russell read a paper on Artificial Lighting in Dentistry." He mentioned three methods of illumination for this purpose, as follows: general lighting to supplement daylight, or take its place entirely; to generate light within the mouth for viewing surfaces by light reflected from them; to generate light within the mouth for viewing tissues by light transmitted through them. In view of the very serious shortcomings of present illuminators of all three forms, it is hoped by the profession that improvements will soon be forthcoming. Important points for consideration are heat and color of light size and cost of illuminant.

At the meeting were present ninety members, and seventy invited guests of the medical profession.

Meeting—May, 1921.

The "Lighting of School Buildings" was the subject for the May meeting. In reviewing the subject Dr. William A. Howe, of the New York State Board of Education, stated that some of the fundamentals required by the general scheme of health service are closely related to illumination, especially as from 8 to 15 per cent of children acquire defective vision in the first few years of school. He called upon the illuminating engineer to solve this most important problem.

Dr. Howe then read a paper on the subject for Dr. Frank H. Wood of the State Board, who was unable to attend the meeting. An important point brought out was the requirements of window spacing in relation to floor area. Many difficulties to be overcome in order to accomplish the desired results were reviewed.

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THE MEASUREMENT OF COLOR*

BY DR. C. E. K. MEES

The methods of measuring color fall into two distinct classes, according to whether we wish to measure the sensation of the color produced upon the observer, or the means by which that sensation is produced. When we wish to study the finished product, we need to measure the sensation; thus, it is necessary to have a convenient method of measuring the color of a ribbon so as to match the ribbon at some future time, if we are manufacturing ribbons of a definite shade, a method of measuring and specifying that color is necessary. But if we are dyeing ribbon, we shall be doing it by means of dyes, and it is necessary to have a method of measuring the amount of coloring power which the dyes have. This should be done independently of the color which they produce upon the goods when they are finished and in terms which can be translated at once into the weight of dye which it is necessary to use.

When measuring the amount of material which produces the sensation of color, we must use analytical methods owing to the composite nature of the light with which we have to deal, while when we are dealing with the sensation of color produced, synthetic methods of measurements must be employed. The analytical instrument used for studying the properties of colored objects is the *spectroscope,* which splits up the light into a band of color the intensity of which can be measured. The form of spectroscope which is used is termed a spectrophotometer. By means of the spectrophotometer, curves of absorption of the light can be obtained, and from those curves the amount of colored matter present can be read directly. The spectrophotometer can thus be used for determining the amount of dye present in a given sample, for analyzing a sample of dye into its components should there be two different dyes present, and for detecting any impurity present in a sample. It can also be used in chemical work for studying any chemical reaction in which the components taking part are colored.

*Abstract of paper delivered before the American Chemical Society, Rochester, April, 1921.

The instrument of measuring the sensation of color produced is known as a colorimeter. Various forms of colorimeters are known, most convenient instruments being those which depend upon the colors of the spectrum itself, defining the color of an object in terms of its dominant hue, corresponding to a given position in the spectrum. Any color may then be defined in terms of the spectral position of its dominant hue and of the amount of white light which must be mixed with the spectral color to match the color in question. Thus, in order to measure a green tinted paper, we place the paper so that the light reflected from it falls into the colorimeter. In the instrument we see one part of the field filled with green light from the colored paper and the other part of the field can be illuminated by means of a spectrum to which can be added any proportion of white light that is required. We change the spectral light by means of a drum until the hue appears approximately right, and then add white light until a match is obtained between the two fields seen in the instrument. The dominant hue is now read off directly from the spectral drum and the percentage of admixed white added is measured photometrically in the instrument.

This form of colorimeter is suitable primarily for use in the laboratory, and for use in the works more rugged and simple instruments have been designed, the latest being a subtractive instrument designed in the research laboratory of the Eastman Kodak Company which is based on the use of colored wedges, each wedge absorbing one-third of the color of the spectrum, so that the three wedges are yellow, blue-green, and magenta in color, the yellow wedge absorbing the blue light, the magenta the green light, and the blue the red light. When these wedges are placed over each other in pairs, they will match any color provided that the intensity is adjusted at the same time by the use of a neutral gray wedge which is supplied as the fourth wedge of the instrument. The instrument is made with a number of attachments according to the purpose for which it is required, so that colored solutions, colored glasses, or colored pigments can all be measured by suitable attachments. A modified form of the instrument has been designed for use in measuring vegetable oils and especially for the use with cottonseed oil.

There is no doubt that colorimeters are just beginning to be

used in the industries and that their use will rapidly increase, especially in the chemical industries. At the same time, the analytical measurement of color by means of the spectrophotometer will find many applications which are not at present apparent.

THE RESPONSE OF THE AVERAGE PUPIL TO VARIOUS INTENSITIES OF LIGHT*

BY PRENTICE REEVES

In the first part of the experiment instantaneous flashlight photographs were taken of two observers for eight brightness levels including total darkness at one end and the just tolerable reflection of sunlight from white drawing paper at the other end. The effect of exposing one or both eyes to each brightness level was shown with both observers.

From these results six brightness levels were chosen, and the pupils of six observers were measured, one of the first observers being used in this series as a check of the method.

By taking motion pictures of an eye, the rates of opening and closing of the pupil were measured as the pupil closed from its maximum opening to the minimum and as it opened from the minimum to the maximum.

The average pupil contracts in less than five seconds and the greater part of the contraction occurs within the first two seconds. The same number of minutes are required for the same pupil to expand.

The curves plotted for the different observers are similar in shape, although the values show marked individual differences between observers.

*Abstract from *Journal* of the Optical Society, p. 35-43, 4, March, 1920.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XVI AUGUST 30, 1921 No. 6

CONVENTION NOTES

The fifteenth annual convention of the Illuminating Engineering Society will be held in Rochester, N. Y., September 26-29, inclusive. The convention headquarters will be at the Powers Hotel.

GENERAL CONVENTION COMMITTEE

Robert M. Searle, Chairman—Rochester Gas & Electric Corp.
Clarence Wheeler, Vice-Chairman—Wheeler Green Electric Co.
Frank C. Taylor, Secretary—Rochester Gas & Electric Corp.
John F. Ancona—American Society Mechanical Engineers.
Otis A Barber—Wheeler Green Electric Co.
Robert J. Barker—Westinghouse Electric Mfg. Co.
J. Rowley Clark—Phillips Electric Co.
W. J. Conley—University of Rochester.
H. W. Davison—Industrial Electric Co.
Bernard E. Finucane—Rochester Electric Supply Co.
A. J. Free—Rochester Optometric Society.
Adolph Hertz—New York Edison Co.
Theo. R. Huber—Huber Electric Co.
L. A. Jones—Eastman Kodak Co.
G. Fred Laube—Laube Electric Co.
Clarence L. Law—New York Edison Co.
Preston S. Millar—Electrical Testing Laboratories.
D. McFarlan Moore—Edison Lamp Works of G. E. Co.
Henry W. Morgan—Chamber of Commerce.
J. J. O'Connell—O'Connell Electric Co.
Max Poser—Bausch & Lomb Optical Co.
Ruden W. Post—Rochester Engineering Society.
H. E. Reddick—Ivanhoe Regent Works of G. E. Co.
E. A. Roeser—Rochester Gas & Electric Corp.
Henry J. Schiefer, Jr.—American Institute of Electrical Engineers.
H. C. Ward—General Electric Co.

SUB-COMMITTEES

Finance Committee
Robert M. Searle, Chairman
H. W. Morgan H. E. Reddick

Transportation Committee
B. E. Finucane, Chairman
H. W. Davison
Clarence L. Law
Horace W. McDowell
H. E. Reddick

Publicity Committee
G. Fred Laube, Chairman
Joseph P. MacSweeney
Ruden W. Post
John R. Powers
Ralph C. Rodgers

Attendance and Local Arrangements Committee
H. C. Ward, Chairman
John F. Ancona
Theodore R. Huber
D. McFarlan Moore
E. A. Roeser
Henry J. Schiefer, Jr.

Entertainment Committee
Otis A. Barber, Chairman
R. J. Barker J. J. O'Connell
J. R. Clark Edgar A. Scheibe
W. J. Conley William Skiff
L. A. Jones

PROGRAM

MONDAY, SEPTEMBER 26

9:30 A. M. to 12:30 P. M. ....Registration
2:15 to 5:00 P. M. ....Opening Session
Evening ....President's Reception

TUESDAY, SEPTEMBER 27

9:15 A. M. to 12:30 P. M. ....General Papers Session
2:15 to 5:00 P. M. ....General Papers Session
Evening ....Animal Light and Luminescence

WEDNESDAY, SEPTEMBER 28

9:15 A. M. to 12:30 P. M. ....General Papers Session
2:00 to 5:00 P. M. ....Inspection Trips and Entertainment
Evening ....Subscription Banquet

THURSDAY, SEPTEMBER 29

9:15 A. M. to 12:30 P. M. ....General Papers Session
2:15 to 5:00 P. M. ....General Papers Session
Evening ....Street Lighting Inspection Tour

1921 CONVENTION PAPERS PROGRAM

MONDAY, SEPTEMBER 26, 2:15 P. M.

OPENING FORMALITIES

Presidential Address ....General George H. Harries
Report of Council by General Secretary ....Clarence L. Law
A Year's Progress in Lighting and Illumination
Committee on Progress (F. E. Cady, *Chairman*)
Further Standardization of Nomenclature
Committee on Nomenclature and Standards (A. E. Kennelly, *Chairman*)
The Paris Meeting of the International Commission on Illumination
Edward P. Hyde
Code of Lighting Factories, Mills and Other Work Places
Committee on Lighting Legislation (L. B. Marks, *Chairman*)

TUESDAY, SEPTEMBER 27, 9:30 A. M.

Pathological Effects of Radiation on the Eye........Louis Bell and F. H. Verhoeff
The Effect of Variations of Visual Angle and Intensity and Composition of Light on Important Ocular Functions......C. E. Ferree and Gertrude Rand
Eye Fatigue in Industry ....Max Poser
Some Properties and Limitations of Optical Material................W. B. Rayton

TUESDAY, SEPTEMBER 27, 2:15 P. M.

Sky Brightness and Daylight Illumination Measurements
Committee on Sky Brightness (H. H. Kimball, *Chairman*)
Color Temperature and Brightness of Various Illuminants
E. P. Hyde and W. E. Forsythe
A Low-Voltage, Self-starting, Neon-Tungsten Arc-Incandescent Lamp
D. McFarlan Moore
Incandescent Lamp Temperatures as Related to Modern Lighting Practice
Willard C. Brown and Chester L. Dows
The Code of Fixture Design and Installation
Committee to Cooperate with Fixture Manufacturers

TUESDAY, SEPTEMBER 27, 8:15 P. M.

Animal Light ....E. Newton Harvey
Luminescence as a Factor in Artificial Lighting ....Edward L. Nichols

WEDNESDAY, SEPTEMBER 28, 9:15 A. M.

Present Status of Automobile Headlighting Regulation
Committee on Motor Vehicle Lighting (C. H. Sharp, *Chairman*)
A Determination by Various Drivers of the Desired Road Illumination from Automobile Headlamps.................H. H. Magdsick and R. N. Falge
Motor Vehicle Headlighting in Massachusetts......................A. W. Devine
The Theory of the Flicker Photometer ....A. H. Taylor
Paints for Integrating Spheres.................................A. H. Taylor
Interlaboratory Photometric Measurements of Gas Filled Tungsten Lamps
F. E. Cady and W. E. Forsythe

THURSDAY, SEPTEMBER 29, 9:15 A. M.

Illuminating Engineering Factors in Electric Sign Design..........C. A. Atherton
Illumination and Traffic Accidents—Statistics from Thirty-two Cities
E. A. Anderson and O. F. Haas
Merchandising Illumination......................................W. L. Goodwin

THURSDAY, SEPTEMBER 29, 2:15 P. M.

The Lighting of Public Buildings....................A. L. Powell and E. Parker
Recent Departures from the Usual Methods in Lighting Public Spaces and Offices ....A. D. Curtis and J. L. Stair
The Lighting of Clothing Factories.................A. B. Oday and R. W. Peden

CLOSING FORMALITIES

Induction of President-Elect.........................Dr. George S. Crampton

COUNCIL NOTES

Upon recommendation of the Board of Examiners the following were elected to membership at the July 14th meeting of the Executive Committee:

Seven Members

CYRUS BARNES,
General Sales Manager,
Charles H. Tenney & Co.,
201 Devonshire St.,
Boston, Mass.

WALTER V. BATSON,
Consulting Elec. Engineer,
Hollis French & Allen Hubbard,
210 South St.,
Boston, Mass.

WARD F. DAVIDSON,
Asst. Prof. of Elec. Engineering,
University of Michigan,
268 Engineering Building,
Ann Arbor, Mich.

ALBERT EDWARD GOODCHILD,
Manager,
Fred J. Smith, Elec. Contractors,
128 St. Peters Street,
Montreal, Canada.

E. J. SPENCER,
Secretary-Manager,
St. Louis Electric Board of Trade,
1298 Arcade Bldg.,
St. Louis, Mo.

CLYDE P. TRUEAX,
Treasurer and Elec. Engineer,
Wolf, Sexton, Harper & Trueax, Inc.,
7 N. Madison St.,
Chicago, Ill.

R. F. WHITNEY,
First Vice-President and General Manager,
Fall River Electric Light Co.,
Fall River, Mass.

Four Associate Members

ALFRED W. BEUTTELL,
A. W. Beuttell, Ltd.,
Grafton Road Works,
Perren Street N. W. 5,
Kentish Town, London,
England.

YUTAKA FUKUDA,
Electrical Engineer,
Japan Hydraulic Power Co., Ltd.,
Tokyo, Japan.

GATES HARPEL,
Commercial Engineer,
Westinghouse Electric and Mfg. Co.,
George Cutter Works,
South Bend, Ind.

CHARLES J. STAHL,
Commercial Engineer,
Westinghouse Electric and Mfg. Co.,
Notre Dame and Division Sts.,
South Bend, Ind.

Three Sustaining Members

RELIANCE METAL SPINNING AND STAMPING CO.,
160 John Street,
Brooklyn, N. Y.

SOCIETA IDROELETTRICA PIEMONTE,
Turin, Italy.

R. WILLIAMSON AND CO.,
Washington and Jefferson Sts.,
Chicago, Ill.

Confirmation of Appointments

The appointment of W. R. M'Coy to serve as a member of the Board of Examiners for the balance of the fiscal year was confirmed.

Society Headquarters

General Secretary Law reported that the matter of Society headquarters had

been arranged, and that the General Offices would be moved on or about July 15, 1921, to Room 1605 of the Engineering Societies Building.

Resolution regarding death of Dr. Edward B. Rosa

The following resolution regarding the death of Dr. Edward B. Rosa was adopted and ordered incorporated in the regular minutes of the Society:

WHEREAS, the death of Dr. Edward B. Rosa removes from our membership a distinguished member and a steadfast supporter of the Illuminating Engineering Society, who has served at various times as Director, as Chairman of technical committees and as a contributor to the proceedings of the Society, and

WHEREAS, his loss is deeply felt by the officers, Council and membership of the Society,

THEREFORE BE IT

RESOLVED, that the Council of the Illuminating Engineering Society expresses its profound regret and sorrow at the death of Dr. Rosa and extends its sympathy and condolences to the bereaved family.

NEWS ITEMS

Belgium Honors General Harries

Brig.-Gen. George H. Harries, head of the allied commission in charge of prisoners of war in Germany after the armistice, has been decorated with the Order of Leopold by the Belgian ambassador, Baron de Cartier, in recognition of his services in behalf of Belgian prisoners. The ceremony took place July 22, 1921, at the Belgian embassy.

Ohio Adopts Headlighting Law

A law was passed at the recent session of the Ohio Legislature requiring in a general way automobile head lighting devices to give adequate road illumination and to avoid glare. The approval of devices was placed in the hands of the State Highway Commissioner, Mr. L. C. Herrick. Mr. Herrick has appointed Professor F. C. Caldwell of the Ohio State University, Chairman of a committee of five to draw up specifications interpretating the law. It is expected that these specifications will follow closely those of the Society. Mr. Herrick has also asked for the cooperation of the Ohio Engineering Experiment Station in the necessary testing and approval of head lighting devices. This work will also be under Professor Caldwell's direction. The law goes into effect on August 16th.

COLOR AND ITS APPLICATION.

M. Luckiesh, of Nela Research Laboratories has revised his book on "Color and its Application." The treatise will be helpful to those interested in any of the arts involving the science of color. The object of this book is not only to discuss the many applications of color, but to establish a sound scientific basis for these applications. It is a discussion of light in relation to color, and the production, measurement and analysis of color. Considerable attention is given to the relation of color and vision, the physiological and psychological phenomena of vision being of great importance in every application of color. The book is authoritative and well illustrated, and for this new second edition some changes have been made in the original text, and an extensive chapter of useful data and methods for their use has been added.

ILLUMINATION INDEX.

PREPARED BY THE COMMITTEE ON PROGRESS.

An index of reference to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y,

Electrical World

Are Gas-Filled Lamps Going to Supplant the Vacuum Types?—	Editorial	June 25	1466
"Better Illumination" Exhibition Makes Good Start at Boston—		June 25	505
One-Design Lighting Fixture Plug and Receptacle to Be Made—		July 9	91
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Ornamental Lighting for Cleveland Parks—	C. G. Beckwith	July 23	157
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Electrician

Miners' Electric Safety Lamps—		July 1	18

Elektrotechische Zeitschrift

Geschichte der Metallfadenlampe—	C. Auer von Welsbach	May 5	453
Neue Kinolampe—		June 2	601
Die Gluühkörper und der Krieg—		June 16	656

Elektrotechnischer Anzeiger

Reflektoren fur elektrische Beleuchtung (also p. 477, May 12, 1921)—	Constantin Loebner	May 11	467
Zur Betriebsbeleuchtung in der Elektro-Industrie—	Willy Hacker	June 1	566

Gas Journal

Research and the Institution—		June 1	474
Lighting of the New Southwark Bridge—		June 22	694
National Physical Laboratory, Report for the year 1920—		June 29	736
The Value of Research Work—		July 6	21

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Gasbeschaffenheit und Lichteffekt—	Terres and Hildegard Straub	May 14	309

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Zur Kenntnis des Innenkegels der Bunsenflamme—		June 2	259
Monthly Abstract Bulletin			
New Projection Lamps with High Light-Intensity (Focus, March 10, 1921, p. 92)—	O. Mente	June	234
Nature			
The Safeguarding of Research—		June 16	481
Philosophical Magazine			
The Effect of an Electric Current on the Photo-Electric Effect—	Allen G. Shenstone	June	916
Physical Review			
The Luminescence of Certain Oxides Sublimed in the Electric Arc—	E. L. Nichols and D. T. Wilber	June	707
Physikalische Berichte, Vol. II, No. 9			
Beleuchtungskontrast und deutliches Sehen. (D Opt. Wochenschr, 7, 1921, p. 129)—	H. Lux		538
Physikalische Berichte, Vol. II, No. 11			
Die Grudlagen der Farbenphotographie. (Das Atelier des Photographen, 28, p. 13, 1921)—	E. Schröder		647
Physikalische Zeitschrift			
Himmelshelligkeit, Himmelspolarisation und Sonnenintensitat in Davos 1911-1918 (Book Review)—	C. Dorno	June 1	342
Popular Mechanics			
No Slides Necessary for New Daylight Projector—		August	208

Railway Electrical Engineer			
Properly Lighted Buildings—	Editorial	July	260
Electric Lighting of Railway Buildings—	J. H. Kurlander	July	271
Revue Generale de L'Electricite			
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Science Abstracts, "A"			
Sensitiveness of Different Parts of the Retina (*Brit. Astron. Assoc., J.* Nov., 1920, *Roy. Astron. Soc., Canada, J.* 15. p. 84, Feb., 1921)—	R. L. Waterfield	May 31,	342
The Wedge Method of Photometry (*Phot. J.* 16, p. 93, Feb., 1921)—	G. I. Higson	May 31	345
Suggested Methods of Secret Signalling (*Preuss, Akad. Wiss. Berlin, Ber.*, 25, p. 443, 1920)—	E. Beckmann and P. Knipping	May 31	346
Science Abstracts "B"			
The Actual Condition of Electric Public Lighting in Italy *Elettrotecnica,* 8, p. 126, Feb. 23, 1921)—	G. Peri	May 31	262
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Daylight Projection of Opaque Subjects—	George Gaulois	July 9	29
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Flowers that Flash—		July	35
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Zeitschrift fur Instrumentenkunde			
Zur Kenntnis des Purkinjeschen Phänomens. (*Sitz. d. Wiener Akad.,* 27, s. 1829, 1918, u. 128 s. 71, 1919)—	Franz Exner	April	125

Das Graukeilphotometer im Dienste der pfanzenkultur. (*Sitz. d. Wiener Akad.*, 127, s. 2283. 1918)—	Walter Hecht	April	127
Die Tätigkeit der. Physikalisch-Technischen Reichsanstalt im Jahre, 1920—		May	129
Zeitschrift für Psychologie U. Physiologie der Sinnesorgane, Abt. II			
Über den Farbenkontrast und die sog. Berucksichtigung der farbigen Beleuchtung—	E. R. Jaensch	April	165
Über Farbenkonstanz und Farbentransformation—	Ostwald Kroh	April	181
Studien zur zentralen Transformation der Farben—	Georg Marzynski	June	45

SEARCHLIGHT EQUIPMENT FOR MOTOR BOATS*

BY MILO C. CAUGHREAN**

The requirements for motor boat lighting in Southeastern Alaska led the author to study this problem. He found the requirements to be clear discernment of objects at about 1000 feet with a minimum amount of stray light. For practical reasons the source should be of as low voltage and amperage as possible. The author's attempts to fulfill these requirements led to the adoption of an incandescent electric lamp having a concentrated filament at the focal point of a spherical sector reflecting shell or shield. The sperical mirror is so placed as to obstruct direct light from the filament while reenforcing the latter's light output in the familiar manner.

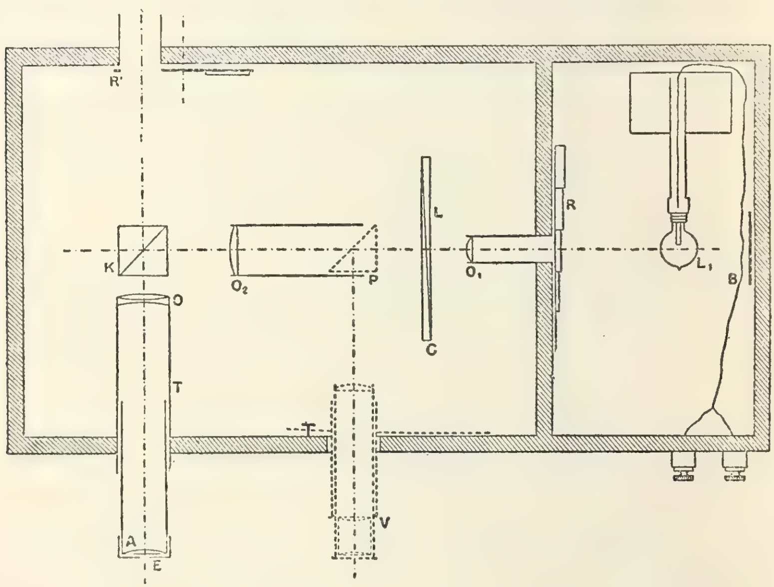
*Abstract of paper presented before the San Francisco Bays Cities Chapter, March 23, 1921.
** Caughrean Fedderson Corp., Ketchikan, Alaska.

A UNIVERSAL PHOTOMETER WITHOUT DIFFUSING SCREEN*

BY H. BUISSON AND CH. FABRY

This apparatus which is intended primarily for the photometry of very distant or very feeble sources of light, is illustrated in the figure.

The light from the source to be measured passes through the Lummer-Brodhun cube K and by the lens O an image of the source is formed in the center of the ocular diaphragm E. which has an aperture of 4 mm. Similarly an image of the comparison lamp L is formed at the same point. The eye placed at E then



Cross-sectional View of Photometer.

sees the two portions of the Lummer cube illuminated in the ordinary manner, but at a far higher intensity than would be possible if diffusing screens had been interposed. Photometric measurements are made by the aid of the photometric absorbing wedge C, the scale of which can be extended by the use of absorbing glasses R and R′. The scale attached to the wedge C is read through the reading glass V, being seen against a white

* Abstract from the *Journal de Physique*, 1920, p. 25.

illuminated background at B. The total range of the instrument is said to be from 100,000 to 1. The advantage which the arrangement has over photometers using a diffusing screen is illustrated by the statement that a source of 50 candles placed at 100 meters gives a field photometrically as bright as a white screen receiving 20 lux. The light from Sirius has been measured and found to give an illumination of about 6.10^{-6} lux. It is stated that all the other ordinary measurements of photometry can be made with this instrument.

REFLECTION CHARACTERISTICS OF PROJECTION SCREENS

BY LOYD A. JONES*

In this paper, which was presented before the Society of Motion Picture Engineers in October, 1920, it was pointed out that in a motion picture installation the projection screen is an important factor in the ultimate efficiency of operation and while some attention has been given to the perfection of screen surfaces little quantitative data are available relative to their reflection characteristics. In order to facilitate the measurement of these characteristics a special goniophotometer was designed and constructed. This instrument is described and illustrated by diagrams and photographs. The method of making the measurements and of expressing the results are discussed. Complete distribution curves showing the distribution of the reflected light are given for some thirty-six different surfaces, the greater majority of which are commercial screens used in the motion picture industry. Data on several well-known surfaces such as magnesium carbonate, opal glass, white blotting paper, etc., are given for the sake of comparison. All reflecting powers are expressed in terms of the reflecting power of magnesium carbonate with normal illumination and observation as 100 per cent.

An examination of the data shows that the screens considered may be roughly grouped into three general classes which may be specified as follows—Class A includes those which re-

* Eastman Kodack Co., Rochester, N. Y.

flect a large portion of the incident light within a very narrow angle and very little light at greater angles. Class B includes the screens which are intermediate between the screens represented in Classes A and B. Class C includes those screens which give almost complete diffusion of the incident light. No attempt is made to draw a sharp line of demarcation between these three classes. The names "specular," "semi-diffuse," and "diffuse" may be conveniently applied to Classes A, B, and C, respectively.

Tables are given in which the ratio of the screen brightness when viewed normally and that when viewed at some particular angle is tabulated. It is assumed that this ratio should not be greater than 4 and on this assumption it is possible to choose the screens suitable for a given installation. The mean reflecting power of the various screens for certain angular deviations from the normal are also computed and tabulated. For a given installation in which the maximum angle of view is known, it is, therefore, possible to choose the screen which will give the maximum efficiency with a satisfactory brightness distribution. The data given in this paper apply only to the intensity factor of the reflection characteristics and do not deal quantitatively with such things as color and texture.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I -- SOCIETY AFFAIRS

VOL. XVI — OCTOBER 10, 1921 — No. 7

CONVENTION NOTES

THE FIFTEENTH ANNUAL CONVENTION

The Convention of the Society is calendarially a thing of the past, however, information presented through papers and discussions, the acquaintances renewed, the new friendships established, and memories of the many and varied entertainment features enjoyed, will be ever enduring. To use the expression so often heard repeated during the convention—"It's the best ever"—undoubtedly sums up the general opinion of all.

There were approximately two hundred members and guests present, and due to the well balanced program of most interesting papers, each session was exceptionally well attended. There will appear in the TRANSACTIONS, from time to time, the papers and discussions which will, of course, give to the unfortunate non-convention attending members, an opportunity to digest the interesting and instructive data pertaining to illuminating engineering which was presented. However, when the entertainment and good fellowship features are considered, these same absentees can only be extended sympathy, for they missed a very great deal.

The usual annual, and sometimes boresome, President's reception this year proved to be a lively gloom-dispersing affair. Instead of being held in a formal ballroom, members and guests were given free access to the Rochester Club. Those who wished to dance, found at their disposal, an orchestra whose one delight seemed to be to dispense motion-compelling jazz. Those who preferred a less strenuous evening, were at liberty to indulge in pool, billiards, cards, etc.

On Wednesday evening, the scene shifted to the Manitou Beach Hotel, where the so-called banquet was held. The formal speech and evening dress was tabooed. In addition to a most appetizing dinner, there was dancing and expert entertainers, including the Chairman of the General Convention Committee, who was unanimously acclaimed the star.

The hospitable Rochesterians provided automobiles at all times of the day or night for the convenience of the convention attendants, and were ever ready to supply a personally conducted tour of the city. Luncheons at the Country Club and theatre parties for the ladies, use of the exclusive golf club, inspection of the street lighting systems, and trips through interesting industrial establishments, such as The Eastman Kodak Company, and Bausch & Lomb Optical Company, are further evidences that the Rochester convention was one that will long be remembered.

The officers and members of the General Convention Committee performed a difficult task in a highly efficient and generous manner, and to them are due the thanks of the entire Society.

CONVENTION ATTENDANCE PRIZE

Over ten years ago the institution of a prize for the Section of the Society which most loyally supported the Annual Convention was conceived. It has been the customary feature to present such a prize at the annual banquet. Mr. D. McFarlan Moore, the author of this idea, made the presentation, together with a statement showing the number of delegates who were present from each of the Sections.

The prize was the usual traveling gavel, recently in the possession of the New England Section, and was awarded this year to the Chicago Section. Mr. J. J. Kirk, Secretary of the Chicago Section, accepted the prize in a very fitting manner.

To the member of the Society coming the greatest distance there was awarded a special prize. The recipient of this honor was Mr. Charles M. Masson of Los Angeles, Calif., who accepted the prize, which was an electric flat-iron.

Attendance at the Convention was international, members and guests coming from Canada, England and various parts of the United States.

APPLIED ILLUMINATING ENGINEERING DESERVES MORE CONSIDERATION

From the opto-physical or purely scientific viewpoint of lighting and illumination the activities of the Illuminating Engineering Society are invaluable. If it were not for the classical researches reported before that organization, there would be no single place toward which to look for scientific guidance on the all-important problem of illumination. None the less, it is unfortunate that the valuable information presented audibly reaches so few ears and that it is then stored away in printed form on reference shelves which are consulted all too infrequently.

To us it seems that the remedy is to make the presentation of papers of the society's meetings and then arrange for joint meetings with other societies representing architects, contractors, fixture dealers and men of similar pursuits. Although this has been done spasmodically before, it could profitably be made a regular practice. By featuring the applied-engineering papers, which always have a wider appeal, and making an honest effort to interest the membership of other societies, a larger number of persons can be made to think in terms of lighting fundamentals and may even become interested in the more scientific discussions of the Illuminating Engineering Society.

The lighting code, the paper on relation of highway illumination to accidents and that on lighting public buildings, presented at the annual convention of the Illuminating Engineering Society last week in Rochester, N. Y., are examples of the type of information which has widespread interest.—*Editorial in Electrical World, Oct.* 8, 1921.

In the lighting branch of the electrical industry the Illuminating Engineering Society takes its place as the leader in both theoretical and practical research and development. The Society at its recent convention, details of which are reported on other pages of this issue, took up many subjects of purely theoretical interest insofar as the present development of the art is concerned.

The Society considers the very practical questions involved in the design and manufacture of equipment, the determination of industrial, street and home lighting standards, and many other questions of vital importance to the

consumer as well as the producer of electric lighting service. The Society deserves the hearty support of the industry.—*Editorial in Electrical Review, Oct.* 8, 1921.

SECTION ACTIVITIES

NEW YORK

The New York Section Board of Managers held a meeting on September 14, 1921, to discuss plans for the coming season. The following subjects were announced for the October meeting: "Radio-Luminescence and its Application," by Dr. V. F. Hess of the United States Radium Corporation and "Flashlights and Flashlight Batteries," by Mr. E. H. Mathews of the American Ever Ready Works.

The following Committee Chairmen were appointed: Papers, S. G. Hibben; Membership, Herman Plaut; Attendance and Publicity, E. A. Mills; Dinner and Reception, D. H. Tuck; Exhibition, J. Doyle.

It is hoped that in the near future a complete program will be announced for the remaining meetings.

PHILADELPHIA

The new Board of Managers met on August 22, 1921, to consider organization plans for the new administration. The Chairmen of the following Committees were confirmed: Papers, G. Bertram Regar; Membership, M. C. Huse; Publicity, T. S. Lever; Exhibition, J. J. Reilly; Reception, H. B. Christy.

It was also decided to change the time of the regular Section meetings from the third Friday to the second Tuesday of each month. The Chairman of the Papers Committee presented a tentative program covering the entire year.

On September 9, 1921, the Board of Managers met to discuss certain routine matters.

COUNCIL NOTES

ITEMS OF INTEREST

A meeting of the Council was held at the Powers Hotel in Rochester, N. Y., September 28, 1921, at which members of the new Council were guests. The following were elected to membership upon recommendation of the Board of Examiners:

Two Members

F. Lee Farmer,
Sales Manager,
Beardslee Chandelier Mfg. Co.,
216 So. Jefferson Street,
Chicago, Illinois.

David H. Moore,
Electrical Engineer,
Day & Zimmermann, Inc.,
611 Chestnut Street,
Philadelphia, Pa.

Seven Associate Members

Ernest Bickerstaff,
Assistant Consulting Engineer,
Messrs. Templin & Toogood,
Box 420,
Christ Church,
New Zealand.

Knight Dunlap.
Professor of Experimental Psychology,
The Johns Hopkins University,
Baltimore, Maryland.

Paul S. Malone,
Incandescent Lamp Inspector,
Electrical Testing Laboratories,
Edison Lamp Works,
Newark, N. J.

R. M. PONDELICK,
Inspector of Lamps,
Electrical Testing Laboratories,
80th Street and East End Avenue,
New York, N. Y

JACOB R. STEWART,
Lighting Specialist,
Westinghouse Electric and Manufacturing Company,
Third and Elm Streets,
Cincinnati, Ohio.

JAMES A. TOOHEY,
Sales Engineer,
Holophane Glass Company, Inc.,
Boston, Mass.

VINCENT WALSH,
Electrician,
Kev Unit Lighting System,
258 Broadway,
New York, N. Y.

The General Secretary reported the following change in membership:

Two Members Deceased

CHARLES O. BOND,
United Gas Improvement Company,
1401 Arch Street,
Philadelphia, Pa.

PETER COOPER HEWITT,
18 East 33rd Street,
New York, N. Y.

One Associate Member Deceased

PAUL THATCHER,
Philadelphia Electric Company,
7-9 Chelton Avenue,
Philadelphia, Pa.

DR. GEORGE S. CRAMPTON RESIGNS AS VICE-PRESIDENT

Having been elected President for the next fiscal year Dr. Crampton presented his resignation as Vice-President to take effect October 1, 1921. The Senior Director, Mr. D. McFarlan Moore, was appointed to fill the unexpired term as Vice-President.

NEW DIRECTOR

On account of the advisability of having a Director from Philadelphia, Mr. G. Bertram Regar was appointed to fill the unexpired term of Mr. Moore.

RESOLUTION REGARDING THE DEATH OF CHARLES O. BOND

The following resolution regarding the death of Charles O. Bond, was read by the General Secretary and was adopted and incorporated in the Minutes of the Society. The General Secretary was instructed to transmit a copy of the resolution to the family of the deceased.

RESOLVED, that the Executive Committee of the Council of the Illuminating Engineering Society having learned of the death of our friend and associate, Charles O. Bond, desires to place on record our appreciation of the ability and devotion which he has always shown in the interests of the Society. During the period of his connection with the Society, he served as an active member on various committees and was President of the Society for the year 1913-1914. He gained the admiration and esteem of all who were associated with him and his memory will remain dear to us all. We hereby deplore our loss and offer our profound sympathy and condolence to his family.

RESOLVED, that this tribute be placed on the Minutes of the Society and that the General Secretary be instructed to convey it to his family.

NEWS ITEMS

PUBLIC RELATIONS REPORT AT CHICAGO CONVENTION OF N. E. L. A.

Mr. J. E. Davidson, Vice-President of the Nebraska Power Co., of Omaha, in his report to the Public Relations National Section of the N. E. L. A. at the Chicago Convention makes the following significant statement:

"Take for instance the residential lighting situation. The incandescent lamp was invented forty-one years ago, it has been developed to a remarkable state, but from the point of view of illumination we really have done little or nothing for our residential customers.

We have the old fashioned electroliers with glass shades which produce very inefficient results, and if the customer only knew what constituted good illumination he really would not tolerate it. I believe that it behooves us to get busy and put that over as a service to our customers, because in reality it is a service, and in doing it we can benefit ourselves as well as our customers."

A SCHOOL LIGHTING CODE ADOPTED IN WISCONSIN

The Industrial Commission of Wisconsin adopted a School Lighting Code on August 30, 1921, which was published in the official state paper on September 6, 1921, and in accordance with the statutory provisions became effective thirty days later.

Arrangements are being made to publish the code together with an appendix which will contain some notes on the design of lighting installations to meet the requirements of the code. In this connection a number of the illustrations published in the "Code of Lighting School Buildings" in 1918 by the I. E. S. will be used.

BRIGHTER BROOKLYN MOVEMENT

The Brooklyn Chamber of Commerce has started a Brighter Brooklyn plan, which contemplates improved street lighting and better display lighting, as well as advances in interior lighting.

As a first step in the program, the flood-lighting of the tower of Borough Hall was thrown on with appropriate ceremonies on the evening of September 15th. Following a dinner at the Chamber of Commerce, the exercises took place in front of Borough Hall, a speakers stand having been erected on the steps.

A large crowd was gathered to witness the turning on of the light by Borough President Riegelmann. The Assistant Commissioner of Water Supply Gas and Electricity and other municipal officials participated. Among the I. E. S. members taking part were Edward L. Cox, Marshall T. Gleason, F. J. McGuire, G. H. Stickney.

DR. GEORGE S. CRAMPTON

PRESIDENT 1921–1922

At the recent convention of the Illuminating Engineering Society held in Rochester, New York, Dr. George S. Crampton of Philadelphia, succeeded General George H. Harries of Chicago as National President. This is the first time that the society has honored an oculist in this manner and it may be taken as an indication that the society not only recognizes the importance of the protection of our visual organs through proper illumination but that it holds true to its traditional purpose as stated by its first president, namely to gather into its fold the various interests that are identified with the development of the science and art of illumination in all its phases.

Dr. Crampton served in France in the recent war as Major and Director of the four field hospitals of the Twenty-eighth Division, he remained in Paris during the two months after the return of the Division as Lieutenant Colonel in charge of one of the medical departments of the Paris District.

Dr. George S. Crampton, the son of Richard and Martha Betty Crampton, was born in Rock Island, Illinois on March 10, 1874. After graduating from the High School of that City he attended Augustana College, and Kemper Hall of Griswold College.

Although his early ambitions were toward the study of Electrical Engineering, a trick of fate took him to Philadelphia in 1894 where he matriculated in the Medical School of the University of Pennsylvania from which he graduated four years later. Following this he spent three years in European travel and study.

Upon his return three and a half years were spent at work in the Ayer Clinical Laboratory and as Resident Physician in the Pennsylvania Hospital. Then came the decision to make the study of the eye his life work. In 1907 he married Hazel Smedes of Vicksburg, Mississippi.

Dr. Crampton's affiliations are as follows: Professor of Ophthalmology, Graduate School of Medicine, University of Pennsylvania in charge of the Department of Optics and Refraction; Fellow of the College of Physicians of Philadelphia; Member of the American Ophthalmological Society; the American Academy of Ophtholmology and Oto-Laryngology and of the American Medical Association; Member of the Committee on Science and the Arts of the Franklin Institute; Member of the Engineers

Part I 100^a

DR. GEORGE S. CRAMPTON
President 1921–1922

CHARLES OTIS BOND
1870–1921

Club of Philadelphia; Chief of the Ophthalmological Clinic, Pennsylvania Hospital and Ophthalmologist to the Philadelphia Hospital for Contageous Diseases.

In March 1914, Dr. Crampton was elected to membership in the Illuminating Engineering Society. He has taken a very active interest in the development of the Society, in the work of various committees and serving as Chairman of the Philadelphia Section for 1914-1915, as Vice-President for 1916-1917, 1917-1918 and 1920-1921.

OBITUARY

Charles Otis Bond, ninth President of the Illuminating Engineering Society, died at his home in Collegeville, Pennsylvania, on Tuesday, August 2, 1921. His death deprives the Society of one of its staunchest and most valuable supporters, and its officers and many of its members of a friend whom they had come to appreciate and esteem through years of co-operation in the cause of good lighting. Mr. Bond's unswerving honesty, his earnestness of purpose and conduct, displayed in everything that he undertook, his broadmindedness and his charity commanded respect from all with whom he came into contact, even from those who occasionally held divergent views. His influence in cementing good relations between the gas and electric fraternities which met on common ground in the Society's activities was of the very greatest importance, and continues to be reflected in the harmony which prevails between these interests in the work of improving illumination conditions.

Mr. Bond's service to the Society, both before and after his term as President, included technical contributions in the form of papers and of service upon such committees as the Committee on Research, the Committee on Nomenclature and Standards, the Committee on Lighting Legislation and administrative work upon such committees as that on Sustaining Membership. He was at all times active in the Philadelphia Section, where his influence was wielded constructively for several years.

Mr. Bond was born at Lehigh, Iowa, November 16, 1870. He was appointed to the U. S. Naval Academy in 1886, graduating with his class in 1890. He resigned from the Navy in 1892, but returned to serve as Lieutenant in Cuban waters during the Spanish-American War. After teaching school in Lehigh and in Rochester, he became a member of the technical force of the Philadelphia Gas Improvement Company in 1896 and remained in the employ of that company and its successor until his death.

His association with the manufacture, distribution and use of gas, and more particularly with the problem of delivering a uniform high-candle-power gas to conform to contractual obligations resulted in his undertaking pioneer work in this field. In the course of this work he introduced into this country and put into daily operation the first pentane lamps which were obtained from England. He also invented the dew-point hygrometer, facilitating the determination of the lowest temperature of gas in the mains. His technical papers on gas photometry and the apparatus and methods thereof have been to a very considerable extent the basis of practice by gas companies in the United States. His leadership in these matters continued throughout the preliminary discussion of a heat standard for gas and his early work in the investigation of calorimeters was instrumental in bringing about a selection of the type which is now in general use in this country for such purposes.

As Director of the Physical Laboratory of the United Gas Improvement Company Mr. Bond interested himself in investigations of gas lamps, their design and improvement, in the more obscure problems of photometry, and under his guidance the Physical Laboratory contributed largely to the advancement of knowledge in these matters.

Mr. Bond was an active member of the Presbyterian Church. He not only won the respect of his associates and contemporaries through his careful, accurate mental processes, but through kindliness and vigor of his character as a technician, a churchman, and member of the general community. He undertook service only in those causes that he believed to be ideally right, of advantage to the community, or developmental of the sciences and arts, and in all such things he manifested zeal, enthusiasm and optimism. He fought for his ideals. He was militant against the forces of evil wherever he saw them—in business, in civic, and in church life, and the uprightness of his purposes was always respected by those with whom he differed in either methods or principles.

In 1895 he married Mathilde Zeller. Of this union there are seven children. The eldest daughter, Barbara, is the wife of Dr. W. Harvey Perkins, engaged with her husband in missionary work in Siam. A son, C. O. Bond, Jr., is a cadet in the U. S. Naval Academy. In these occupations of the children his friends will see reflected that zeal for service which was so prominent a characteristic of the father.

Mr. Bond's funeral took place on Friday, August 5, at the Forrest Presbyterian Church, Germantown, Philadelphia.

ILLUMINATION INDEX.

PREPARED BY THE COMMITTEE ON PROGRESS.

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SOME FACTORS AFFECTING VISUAL ACUITY*

BY CHARLES SHEARD**

After a brief introduction as to the character of the visual acuity charts, and their construction, now commonly in use in clinics and offices, the author cites the following factors which may affect visual acuity tests.

(1) The Snellen test types of our clinics and offices are but assumed standards which are found to serve us rather conveniently in the practical work of ocular refraction. The acuity depends not only upon the quality of the dioptric apparatus but also upon that of the retina, of the optic nerve and of the brain.

(2) It is a well-known fact that some letters of the same size and subtending as a whole the same visual angle are much more easily read than others. For if we take the ability to recognize the letter B at the five minute angle as standard or $V=1$, we find that the average acuity required for the letter L, for example, of the same size and subtending the same visual angle is about $V=0.7$.

(3) Age affects the acuity for reasons which are obvious. In general there is in the healthy eye a slight but uniform decrease in acuity from the fortieth year on.

(4) The influence of pupillary diameter upon visual acuity is quite marked; the optimum pupil corresponds to about 3 or 4 mm. diameter. Hence, eyes having equality of functions and structure in all particulars and yet varying unduly in pupillary area will have quite appreciable acuity differences.

(5) The condition of retinal adaptation plays a part in acuity conditions, for in general it is found that (a) for low intensities of illumination the visual acuity increases with darkness adaptation, (b) for average luminosities it remains the same whether the retina is adapted or not, and (c) for high intensities of illumination the acuity decreases with darkness adaptation.

(6) All methods of observation and experimentation show conclusively that the visual acuity increases at first quite rapidly with small changes in the illumination but that finally a very large increase in luminosity is demanded in order to change the acuity by a small percentage. This point is of significance in the matter of test-card lighting.

*Abstract from *American Journal of Physiological Optics*, Vol. 2, No. 2, April, 1921, pp. 168-184

**Editor, *American Journal of Physiological Optics*.

(7) Visual acuity increases and decreases more slowly under colored illuminations having short wave-lengths than for the less refrangible radiations for any given variation in the objective luminous intensity. Also the acuity is greater in yellow light and decreases through red, green and blue.

(8) The proper maintenance of visual efficiency demands attention to (a) the sensitiveness of the eye to differences of luminosity and (b) the acuity of the eye. A working rule suggested is that the illumination of any surface requiring the continued application of the eyes shall be such that the light reflected or transmitted by it shall be equivalent to a luminosity of approximately one lumen per square foot.

A LIGHT SCALE KEYBOARD AND RHEOSTAT*

BY MARY HALLOCK-GREENEWALT

The writer as a pianist conceived a desire for expression through light. The requirements were for a light scale, smooth and orderly in operation, offering fine gradations of light intensity and of the spectral colors. These must be under ready control in order to make it possible for the performer to employ any desired gradations and nuances for purposes of light expression. With such adequate mechanical and electrical equipment the artist may use light as a means of abstract and emotional expression distinct from its employment for decorative purposes.

"If, for example, simply by a rising inflection of the voice one may express a question: Yes? Then, with the moment properly staged, a raising of the light with that meaning pointed to, will do the same thing.

"A sodden, darkish light could be made to express sullenness; an absence of light, depth of gloom; bright light, joy and much of the shadings of feeling which like those of music are beyond the telling by words."

The writer traces the differences between variable properties of sound and of color and then proceeds to describe a rheostat which has been developed in order to meet the requirements of light expression, and exhibits a "light and music" phonograph designed for the co-ordination of expression through sound and light.

*Abstract of Paper presented before the Philadelphia Section of the I. E. S., Feb. 20, 1920.

TRANSACTIONS
OF THE
Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XVI NOVEMBER 20, 1921 No. 8

SECTION ACTIVITIES

NEW ENGLAND

Meeting—October, 1921

The New England Section met on October 18, at the Rogers Building, Massachusetts Institute of Technology, 491 Boylston Street, Boston, Mass. Here is housed Boston's Permanent Industrial Lighting Exhibit and because the subject was "Illumination of Textile Mills" it was quite appropriate that the first paper of the year should be presented at this location.

Mr. J. M. Ketch, of Nela Park, Cleveland, Ohio, read the paper, which was enthusiastically received and was followed by a very interesting discussion. There were present about fifty members and guests.

NEW YORK

Meeting—October, 1921

The first meeting of the New York Section was held on October 20. A paper "Radio-Luminescence and its Application," by Dr. V. F. Hess of the United States Radium Corp., and a paper on "Flashlights and Flashlight Batteries," by E. H. Mathews of the American Ever Ready Works, were presented. The meeting was well attended, there being about 200 members and guests present. Representatives from the following organizations were present: Metropolitan District of the New York State Association of Electrical Contractors and Dealers, New York Division of National Council Lighting Fixture Manufactures, and Association of Lighting Fixture Manufacturers, Inc.

The annual meeting of the Society was held prior to the Section meeting. Mr. D. McFarlan Moore, Vice-President, presided, and the annual report of the General Secretary was presented to the Society for approval.

Meeting—November, 1921

The meeting on November 17 was designated as a special ladies' night and the meeting itself was unique. The color lighting recently installed in St. Mark's Church in-the-Bouwerie was studied. Dr. W. N. Guthrie, Rector, held a short symbolical service for the members of the Society at 8 P. M., during which the color effects of this installation were demonstrated. At the close of the service the members adjourned to the parish hall, where Mr. L. H. Graves read a paper on the technical and mechanical features of the lighting installation in St. Mark's Church. A very interesting discussion followed. The meeting was well attended, about 225 members and guests being present.

PHILADELPHIA

Meeting—October, 1921

The first meeting of the Section was held on October 27 in conjunction with the Electrical Conference which is com-

posed of the electrical contractors, wiremen and Fire Underwriters' Inspectors. The speaker was Mr. Preston S. Millar of New York, whose subject was "The Value of a Knowledge of Illumination Principles to the Electrical Contractor." He also presented a number of demonstrations of lighting effects which were observed with interest by the audience. No dinner preceded this meeting and the attendance was approximately 600.

Meeting—November, 1921

The meeting of the Philadelphia Section on November 10 was a joint meeting with the Building Owners and Building Managers Association. It was preceded by a separate dinner by each organization, there being fourteen present at the Illuminating Engineering Society dinner.

The speaker at the meeting was Dr. Henry A. Gardner of the Institute of Paint and Varnish Research, Washington, D. C., and his subject was "Paint as an Aid to Illumination." The speaker showed samples of various colored papers with the reflection factor marked thereon, and followed this with a number of lantern slides giving similar information as well for paints of different composition. The practical side of the paper consisted of a description, with lantern slides, of the use of paint guns for spraying paint over large surfaces by means of compressed air. A general discussion on both the theory and practice followed. The approximate attendance was thirty-five.

At the meeting of the Board of Managers of the Philadelphia Section on November 10, 1921, the following resolution on the death of Mr. Charles O. Bond was adopted:

"WHEREAS, Charles O. Bond was for many years closely associated with the Philadelphia Section of the Illuminating Engineering Society, both as a member and an official and where he was highly regarded by those who knew him, and

WHEREAS, his death in August, 1921, has deprived the Society of his service and the members of a friend,

BE IT RESOLVED, that the Board of Managers, on behalf of the members of that Section, takes this opportunity to express its sorrow and to extend to his family its sympathy with the assurance that his memory will remain in kindly thought."

CHICAGO

The Board of Managers met on November 2, and the following Committee Chairmen were appointed: J. J. Kirk, Membership Committee; F. A. Rogers, Reception and Attendance Committee; E. D. Tillson, Papers Committee.

Preliminary discussion of the program took place and it was decided to have a meeting on November 30 at 7:30 P. M. at the Fullerton Hall, Art Institute, jointly with the Western Society of Engineers and the Chicago Section of the A. I. E. E., the speaker to be W. D'Arcy Ryan and the subject "Illumination."

CLEVELAND

The first meeting of the Cleveland Chapter, on November 9, was held jointly with the American Institute of Architects, at which time the subject of "Artificial Lighting" was discussed by Mr. C. S. Schneider of the A. I. A. and Mr. Ward Harrison of the I. E. S.

TORONTO

Meeting—October, 1921

The first meeting of the Toronto Chapter was held on Oct. 17, at which time Mr. George G. Cousins gave an interesting paper on "Automobile Headlights." A number of headlight lenses were placed in a demonstrating reflector

and the beam projected on a screen, suitably marked, to show the contours, relation of the several lenses and the relation of the beams to the road. Comparison between the laws of several States with the law of Ontario was shown in the demonstration.

Three members of the Toronto Chapter were appointed to confer with a committee of the Ontario Motor League, for the placing of a proposition before the proper authorities to adopt a plan for the rational enforcement of anti-glare laws by the establishment of testing stations. The plan, if adopted, would be under the supervision of the police, and its actual operation would be educational in its influence as well as providing means for effective enforcement of the law.

COUNCIL NOTES.

ITEMS OF INTEREST.

At the meeting of the Council on October 13, 1921, the following were elected to membership upon recommendation of the Board of Examiners:

One Member

ORVILLE R. TOMAN,
Manager and District Engineer,
Bedford Light, Heat & Power Co.,
215 Main Street,
Bedford, Iowa.

Three Associate Members

ROBERT COREY DEALE,
Electrical Engineer,
Pond Works of Niles Bement-Pond Company,
Plainfield, New Jersey.

GEORGE NORMAN GARDNER,
Salesman,
Canadian Westinghouse Co., Ltd.,
602 Hastings Street, W.
Vancouver, British Columbia, Canada.

JOHN NEWTON STEPHENS,
Electrical Engineer,
British Thomson Houston Co., Ltd.,
77 Thames Street,
London, England.

Two transfers to Associate Membership were approved as follows:

THEO. H. PISER,
Welsbach Company,
16 Oliver Street,
Boston, Mass.

R. E. TYLER,
Manager,
Philadelphia Branch Office,
Shelby Lamp Division, National Lamp Works of G. E. Company,
1941 Market Street,
Philadelphia, Pa.

One Associate Member Deceased

GEORGE HOLT LUKES,
General Supt.,
Public Service Company of Northern Illinois,
72 West Adams Street,
Chicago, Ill.

CONFIRMATION OF APPOINTMENTS

The appointments of the following chairmen and committee members were confirmed:

Council Executive Committee:

Dr. George S. Crampton, Chairman
Clarence L. Law
L. B. Marks
Preston S. Millar
Walton Forstall

Committee on Finance:

Adolph Hertz, Chairman
D. McFarlan Moore
S. E. Doane

General Board of Examiners:

L. J. Lewinson, Chairman
W. R. M'Coy
W. H. Rolinson

Committee on Progress:

F. E. Cady, Chairman
G. S. Crampton
F. R. Mistersky
W. E. Saunders

Committee on Motor Vehicle Lighting:

Clayton H. Sharp, Chairman
G. N. Chamberlin
P. W. Cobb
E. C. Crittenden
M. W. Hanks
W. F. Little
W. A. McKay
A. L. McMurtry
H. H. Magdsick
L. C. Porter
G. H. Stickney
J. A. Hoeveler
L. E. Voyer, Representative in State of California

Committee on Education:

F. C. Caldwell, Chairman

S. G. Hibben, Chairman Sub-Committee on Popular Education

W. J. Drisko, Chairman Sub-Committee on Technical Schools and Colleges.

F. A. Vaughn, Chairman Sub-Committee on Extension Courses

R. B. Ely, Chairman Sub-Committee on Public Schools

Field Members

A. L. Powell
W. M. Skiff

Committee on Lighting Legislation:

L. B. Marks, Chairman
W. F. Little, Secretary
Louis Bell
W. T. Blackwell
F. C. Caldwell
C. E. Clewell
C. W. Cutler
Ward Harrison
S. G. Hibben
J. A. Hoeveler
A. R. Holden
O. L. Johnson
Clarence L. Law
M. G. Lloyd
M. Luckiesh
R. H. Maurer
A. S. McAllister
G. B. Nichols
W. J. Serrill
R. E. Simpson
G. H. Stickney
L. A. Tanzer
F. A. Vaughn

The following Committees were appointed:

Nomenclature and Standards:

A. E. Kennelly
Clayton H. Sharp
Louis Bell
E. C. Crittenden
W. A. Dorey
E. J. Edwards
E. P. Hyde
C. O. Mailloux
A. S. McAllister
W. E. Saunders
C. P. Steinmetz

Sky Brightness:

H. H. Kimball, Chairman
W. F. Little
L. B. Marks
M. Luckiesh
E. H. Hobbie
Bassett Jones
E. C. Crittenden
I. G. Priest, Advisory Member

Artistic Treatment of Interior Lighting:

S. G. Hibben, Chairman

Committee to Co-operate with Fixture Manufacturers:

M. Luckiesh, Chairman

W. T. Blackwell
S. G. Hibben
R. H. Maurer
A. L. Powell

QUESTION OF ADOPTING THE TERM "LUMINAIRE" AS A GENERAL TERM FOR LIGHTING FIXTURES—After discussion, it was moved that the Committee on Nomenclature and Standards draft a letter for the General Secretary to send out to other Societies and Organizations asking their opinion of the use of this term.

TECHNICAL BULLETIN—It was moved and carried that the Council accept the recommendation of the Special Committee appointed to recommend to the Council regarding the publication of a bulletin on "Lighting the Home by Electricity" prepared by a committee appointed for that purpose. The recommendation was that the Council approve the issuing of a bulletin on "Lighting the Home by Electricity" after it has been approved by the Committee on Papers.

The Council moved that a committee be appointed to recommend a bulletin program and procedure in the physical handling, classifying, indexing, etc., and to report their recommendations to the Council at its next meeting.

The Council moved that a committee be appointed to draft a bulletin on "Lighting the Home by Gas."

NOVEMBER MEETING

At the meeting of the Council on November 10, 1921, the following were elected to membership:

Three Members

HARRISON M. KÜMMERLE,
Lighting Specialist,
115 East 34th Street,
New York, N. Y.

RAYMOND V. OWEN,
Lighting Fixture Designer,
Luminous Unit Co.,
2615 Washington Avenue,
St. Louis, Mo.

EDWARD L. SHERWOOD,
Consulting Engineer,
Leffingwell-Ream Company,
Chicago and New York

Ten Associate Members

MAURICE P. BROGAN,
Lumen Unit Company,
6010 Euclid Avenue,
Cleveland, Ohio.

R. I. BROWN,
Commercial Manager,
Little Rock Railway & Electric Co.,
Little Rock, Arkansas

GEORGE AUBREY CLEWELL,
Lighting Service Department,
Westinghouse Lamp Company,
165 Broadway,
New York, N. Y.

EDWARD A. EVANS,
Salesman,
Westinghouse Lamp Company,
1272 Walker Bank Bldg.,
Salt Lake City, Utah.

STANLEY ALFRED HEMAN,
Draftsman and Lighting Engineer,
Westinghouse Lamp Company.
165 Broadway,
New York, N. Y.

THOMAS S. LEVER, JR.,
Office Manager and Employment Supervisor,
The United Gas Improvement Co.,
24 No. 22d Street,
Philadelphia, Pa.

LEON C. MCARDLE,
Lighting Service Dept.,
The Philadelphia Electric Co.,
1000 Chestnut Street,
Philadelphia, Pa.

C. J. Rhea,
Manager,
The Dillon Lens & Mfg. Co.,
Bridgeport, Ohio.

Walter C. Wagner,
Chief Engineer's Department,
The Philadelphia Electric Co.,
1000 Chestnut Street,
Philadelphia, Pa.

Louis H. Werner,
Vice-President,
Central Union Gas Co.,
529 Courtland Avenue, Bronx,
New York, N. Y.

CONFIRMATION OF APPOINTMENTS

The appointments of the following Chairmen and committee members were confirmed:

Committee on Papers:

H. V. Bozell, Chairman
A. L. Powell, Vice-Chairman
E. A. Anderson
Conrad Berens, Jr.
Julius Daniels
S. G. Hibben
M. G. Lloyd
Howard Lyon
A. S. McAllister
Norman Macdonald
W. L. Plack (Advisory Member)
Chairman of Section Papers Committees.

Committee on Editing and Publication

Norman Macdonald, Chairman
Ralph C. Rodgers

Committee on Membership:

G. Bertram Regar, Chairman
Merritt C. Huse

Committee to Draft Bulletin on Residence Lighting by Gas

Howard Lyon
R. H. Maurer

Consideration of Motion Passed at Convention During Discussion of Sky Brightness Report:—The Council endorsed the work of the U. S. Weather Bureau in their investigations bearing upon the relative importance of sunlight as compared with artificial light.

NEWS ITEMS

Ohio Highways Traffic Association

At a meeting of interested parties on Oct. 26, 1921, in Columbus, Ohio, an organization known as the Ohio Highways Traffic Association was formed for the immediate purpose of promoting good automobile headlights in that state. Mr. C. T. Kelly was made Commissioner and Prof. F. C. Caldwell was made President of the organization.

A number of concerns and individuals who are financially interested in the business have undertaken to raise a considerable fund with which to pay instructors and other workers who will operate under the auspices of this association.

Professional Opportunities

Engineer: There is a position available in a research laboratory for a young man of pleasing personality who is a graduate of electrical engineering. He must possess an analytical or research attitude but should also be able to present new ideas and developments in lighting to others. The work is entirely along the lines of the utilization of light. For one with the proper qualifications this position holds a promising future. L. N. (1)

General Office

Copies of the following issues are desired:

Vol. XV, No. 7, Oct. 10, 1920.
Vol. XVI, No. 3, April 30, 1921

The General Office will pay fifty cents each for copies in good condition of these issues.

LIGHTING LEGISLATION COMMITTEE BULLETIN.

BY L. B. MARKS, *Chairman*

WISCONSIN SCHOOL LIGHTING CODE

This Code, issued by the Wisconsin Industrial Commission, became effective October 6, 1921. It is based upon the I. E. S. Code of Lighting School Buildings but differs from it in several requirements, as will be noted. New York State was the first state to officially recognize the I. E. S. Code as a guide to be followed in passing upon the artificial lighting of school buildings. Wisconsin is the first state actually to adopt a complete school lighting code.

The Wisconsin Code is divided into 3 sections, (1) Application and scope of orders and meaning of terms; (2) Natural lighting; (3) Artificial lighting.

SECTION 2. Under Daylight Requirements it is specified that class and recitation rooms hereafter constructed shall be illuminated by the unilateral or by the bilateral system. The glass area of windows shall be at least 1 square foot of effective glass surface for every 6 square feet of floor surface. Only clear glass shall be used in the lower portion of side windows. Window sills shall be at least 30 in. above the floor. A sill height of 36 to 42 inches is recommended. In general, window heads shall not be less than 11 ft. 4 in. above the floor and in no case shall the top of glass be a greater distance below the ceiling than 12 inches. The height of top of glass above floor shall be such that the ratio of room width to same, (measured at right angles to the glass surface) will not exceed 2¼, except where bilateral lighting is used in which case the room width may be increased to 2½ times the height of top of glass above floor. Where skylights are used no limitation is placed on room width. Exceptions are made in the case of basements, halls, corridors, etc. In a note it is stated that the aim is to secure a sky exposure, for any pupil's desk, of at least 50 "square degrees," preferably 5 degrees vertically and 10 degrees horizontally; where court walls or walls of opposite buildings make it impossible to secure an open sky exposure, such walls are to be finished very light in color and prism glass is to be used in the upper half of the windows.

No windows are permitted in the front wall of a class room or study hall and no blackboards are permitted on the same wall with windows, nor within 4 feet of any window.

Two sets of shades are recommended for each window, one set of tan colored material and another set of dark green. These shades are to be operated on two rollers placed near the level of the meeting rail so that they may be raised or lowered from the middle of the window. This plan is followed in a number of the more modern schools in New York City and is illustrated in the I. E. S. Code of Lighting School Buildings.

It is specified that the ceilings shall be finished with a matte (dull) or semi-matte surface having a reflection factor of at least 70 per cent; and that the walls from ceiling down to top of blackboards, or to height of 6 feet above floor, shall have a matte surface finished with a reflection factor of not less than 25 per cent nor more than 50 per cent. Below the 6 foot level a darker finish may be used.

A table of reflection factors is given for different wall colors. It is specified that the walls of "light" courts shall be finished with a surface having an initial reflection factor of at least 50 per cent.

SECTION 3. Under general requirements it is specified that when the natural illumination falls below twice the minimum values for artificial lighting set forth in the following table, artificial light shall be used.

	(1) Minimum permissible intensity of illumination at the work; Foot-candles	(2) Recommended practice Foot-candles
(a) Storage spaces	0.5	1 - 2
(b) Stairways, corridors, entrances, porticos, etc.	1	2 - 4
(c) Boiler rooms and similar spaces	1	2 - 4
(d) Gymnasiums, auditoriums, assembly rooms, museums, art galleries	2.5	4 and higher
(e) Class, study, recitation rooms, libraries, laboratories, manual training, domestic science, (except sewing)	5	8 and higher
(f) Sewing, drawing, drafting	8	12 and higher

Exception. For existing installations the minimum intensities of Column (1) may be reduced by one-half.

The intensities specified in this table are, in general, almost double those specified in the I. E. S. Code of Lighting School Buildings.

Mention is made of the fact that the admixture of daylight and artificial light is not satisfactory unless the artificial light is derived from lamps designed to produce light having a spectrum like that of daylight. Hence in waning daylight it is usually desirable to pull the window shades and use artificial light exclusively.

The principal artificial lighting must be derived from over-head lamps and not from local lamps placed close to the work

For new installations it is specified that the intensity of the brightest square inch of any overhead lighting unit, visible from any location at which work is performed and located within an angle of 25 degrees above eye-level, shall not exceed 15 candlepower.

The intensity of the brightest square inch of any local lighting unit shall not exceed 3 candlepower.

In school buildings hereafter constructed, the lighting shall be so arranged that the ratio of the illumination at the lightest spot to the illumination at the darkest spot is not greater than 4 to 1.

The concluding paragraphs of the Code contain references to diffusion of light, exit and emergency lighting, switching and controlling apparatus and maintenance.

The Code was prepared by Mr. John A. Hoeveler, Electrical Engineer, Wisconsin Industrial Commission, in co-operation with an advisory committee of which Mr. F. A. Vaughn was a member, representing the Illuminating Engineering Society and the Committee on Lighting Legislation.

MASSACHUSETTS INDUSTRIAL LIGHTING CODE

Pursuant to a resolution adopted at the November meeting of the Advisory Committee, appointed to draw up rules and regulations for lighting factories, mills and other industrial establishments in the State of Massachusetts, the Commissioner of Labor and Industries in that state is planning to promulgate a code. The code is to be advisory for the period of one year, and thereafter to become mandatory, after such amendments are made as may seem desirable after a year's experience and after a public hearing on the code.

The code follows rather closely the lines laid down in the I. E. S. Code of Lighting Factories, Mills and Other Work Places.

Arrangements have been made with Professor Drisko, of the Massachusetts Institute of Technology, to plan a course for the instruction of inspectors of the Department of Labor and Industries along the lines

of the course given to inspectors in the states of New Jersy and Pennsylvania in connection with the operation of the industrial lighting code in those states.

Dr. Louis Bell, of Boston, is chairman of the Advisory Committee and also represents the Committee on Lighting Legislation in this matter.

Massachusetts is the eighth state in the United States to adopt an industrial lighting code, the other states being Pennsylvania, New Jersey, New York, Wisconsin, Oregon, California and Ohio.

ILLUMINATION INDEX.

PREPARED BY THE COMMITTEE ON PROGRESS.

An index of reference to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y,

Electrical World			
Bearing of Illumination Intensity upon Efficiency of Visual Operations—(And editorial)	M. Luckiesh and R. H. Sinden	Oct. 1	663
Progress in Lighting Told at I. E. S. Convention—		Oct. 1	685
Applied Illuminating Engineering Deserves More Consideration—		Oct. 8	704
Highway Illumination is an Important and Relatively Untouched Field of Lighting—		Oct. 8	706
Relation between Street Lighting and Crime—		Oct. 8	728
The Revised Code of Lighting—		Oct. 15	760
Better Illumination Cuts Production Costs—	Ward Harrison, O. F. Haas, F. W. Dopke		763
Electrician			
Welfare Work and Factory Lighting—		Sept. 16	342
A Rugby Church Installation—		Sept. 16	361
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Ein Weg zum Studium und zur Projektierung der Innenbeleuchtun—	J. Ondracek Wien	Dec. 19	595
Elektrotechnische Zeitschrift			
Beleuchtung und Heizung. Scheinwerier mit mehreren Lichtquellen—		July 28	831
Beleuchtung und Heizung. Nachtraglicher Einbau elektr. Beleuchtung in Automobile—		Aug. 11	889
Gas Journal			
Nationally Organized Research—		Sept. 14	587
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Photometrische Prufungen der Physikalisch-Technischen Reichsanstalt im Jahre 1920—		July 30	515
General Electric Review			
A Paint that will not Reflect Ultra Violet Rays—	W. S. Andrews	Oct.	866
Illuminating Engineer (London)			
The Cost of Publication of Scientific Researches—		May	113
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Motion Picture News			
Importance of Proper Illumination of Theatre Interior—		Sept. 17	1519
National Glass Budget			
Neon Lamps in Agriculture—		July 23	7
Nature			
New Facts of Colour Vision—	Dr. F. W. Edridge-Green	Aug. 25	826
Physical Effects Possibly Produced by Vision Observed by Dr. Russ—	Dr. H. Hartridge	Sept. 1	22
Pflüger Archiv für Die Gesamte Physiologie, 189, Heft 1/3			
Untersuchungen uber Lichtemfindlichkeit und Adaptierung des Vogelauges—	Hans Honigmann		1

Philosophical Magazine			
On the Variation of Resistance of Selenium with Temperature—	Snehamoy Datta	Sept.	463
Physical Review			
A Disappearing Filament Optical Pyrometer Free from Diffraction Effects at the Filament—	C. O. Fairchild	Aug.	116
A Direct Reading Spectrophotometer for Measuring the Transmissivity of Liquids—	I. G. Priest	Aug.	127
On the Photoelectric Effect of Alkali Vapors—	Jakob Kunz	Aug.	130
Total Emissive Powers and Resistivities of Tungsten at Incandescence—	A. G. Worthing and W. E. Forsythe	Aug.	144
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On Fechner's Law and the Self-Luminosity of the Eye—	Wm. Peddle		902
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Enginehouse Lighting—		Sept.	334
Revue Generale de L'Electricite			
Lampes à incandescense a filament droit pour recherches de laboratoire et experiences de cours—		Aug. 6	194
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Interior Lighting of Busses—	L. C. Porter and R. W. Jordan	July 20	77
Street Car Lighting—	J. A. Summers	July 20	95
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TRANSACTIONS
OF THE
Illuminating Engineering Society
PART I--SOCIETY AFFAIRS

VOL. XVI DECEMBER 30, 1921 No. 9

SECTION ACTIVITIES

NEW ENGLAND

Meeting—December, 1921.

The New England Section met on December 1 at the Engineers' Club, where Mr. Stephen C. Rogers of the General Electric Company, Lynn, Mass., presented a paper, "A Point Source of Light for Laboratory Use," in which he explained motion picture projection and gave a demonstration with suitable apparatus. The reading of the paper was followed by an interesting discussion. There were about forty-five members and guests present.

NEW YORK

Meeting—December, 1921.

A meeting was held on December 15 at the Engineering Societies Building at 8.00 P. M., the subject "Signal Control of Traffic" was discussed. Three papers were presented, as follows: "Signal Control of Traffic," by John A. Harriss, Special Deputy Police Commissioner, City of New York; "Traffic on Fifth Avenue," by Robert Grier Cooke, President of the Fifth Avenue Association; "Highway Traffic Signalling with Colored Lights," by E. A. Warner, Jr., of the Union Switch and Signal Company. Some remarks were made also by Mr. Joseph H. Friedlander, the designer of the new decorative towers to be installed on Fifth Avenue for the purpose of regulating traffic.

A very interesting discussion was held by the members and guests present, the attendance totaling about one hundred and ten.

PHILADELPHIA

Meeting—December, 1921.

The December meeting of the Philadelphia Section was held on Tuesday, December 13, 1921, at 8.00 P. M. at the Engineers' Club, and was preceded by a dinner at which twenty-seven participated.

It was a combined meeting with the Philadelphia Safety Council, and the speaker was Mr. S. G. Hibben of the Westinghouse Lamp Works, New York, whose subject was "Safety Factors of Industrial Lighting." Mr. Hibben described some of the general principles of the transmission and reflection of light and referred to its color values, shadows and the effect of illumination in industrial establishments. He spoke on the value of good lighting in factories with respect to its influence on the prevention of accidents and on the increase of the output. The discourse was illustrated by a number of demonstrations, and the subject was presented in a most interesting and complete manner.

The attendance at the meeting was fifty-three.

Meetings will be held at the Engineers' Club, of Philadelphia, 1317 Spruce St., at 8:00 P. M. on the second Tuesday of each month. Members of other Chap-

ters and Sections visiting Philadelphia are cordially invited to attend. The following papers, programs for the balance of the year has been adopted.

January 10th, 1922.

"Making Natural Color Motion Picture Films."
By W. V. D. KELLEY, Prizma Inc., Jersey City, N. J.
Ladies' Night.

February 14th, 1922.

"Principles of Illumination Design."
By E. A. ANDERSON, Illuminating Engineer, National Lamp Works, Cleveland, Ohio.

March 14th, 1922.

"Aesthetic and Utilitarian Value of Lighting Fixtures."
By EMILE G. PERROT, Architect, Philadelphia, Pa.

"History and Utilization of Lighting Fixtures."
By STEPAN de KOSENKO, Sterling Bronze Co., New York City, N. Y.
Joint Meeting with the Lighting Fixture Dealers' Society of America.

April 11th, 1922.

"Some Principles of Gas Lighting."
By HOWARD LYON, Physicist, Welsbach Co., Gloucester, N. J.

TORONTO CHAPTER

Meeting—November, 1921.

The Toronto Chapter met on November 21 at the Chemistry and Mining Building of the University of Toronto to discuss a paper "Illumination and Its Relation to Architecture," as presented by Mr. S. G. Hibben of New York. Mr. Hibben demonstrated, with various equipment, light control, the effect of colored lighting, and the relation of shade and shadow in illumination. Also, lantern slides were used in showing good and bad examples of illumination. At this interesting meeting there were present about fifteen members and sixty-three guests.

Meeting—December, 1921.

A paper on "Street Lighting," by Mr. M. B. Hastings of the Winter-Joyner Company, was presented at the meeting of the chapter on December 19. Mr. Hastings gave a very interesting talk on street lighting systems, illustrating the advances that have been made in municipal lighting, especially in the cities, towns and villages of Ontario who have joined the Ontario Hydro-Electric Power Commission municipalities. The different systems of construction in these communities were outlined and shown on lantern slides. Examples of street lighting in different parts of the American continent were illustrated. A very interesting and practical discussion followed the paper on mounting heights of units, maintenance of units and lamp troubles. About twenty-five members and guests were present.

COUNCIL NOTES

ITEMS OF INTEREST.

At the meeting of the Council on December 8, 1921, the following were elected to membership:

Three Members

SAMUEL F. ARBUCKLE, Sales Engineer,
Lighting Division, U. S. Automotive Corp.,
1412 Central Avenue,
Connersville, Indiana.

HERBERT W. DESAIX, Manager,
Watson-Flagg Engineering Co.,
214 Straight Street,
Paterson, N. J.

ROBERT JOHN TORRENS, Electrical Engineer,
U. S. Naval Observatory,
Washington, D. C.

Four Associate Members

FRANK C. BALFOUR, Sales Manager,
Owlite Distributing Company,
307 Union Oil Building,
Los Angeles, Calif.

J. S. KIRKPATRICK, Lighting Specialist,
Holophane Glass Company,
342 Madison Avenue,
New York, N. Y.

FRANK L. SAMPLE,
Illuminating Engineer,
National X-ray Reflector Co.,
Room 65, 146 Summer Street,
Boston, Mass.

WILLIAM L. WALL,
Specialist in Spectacle Optics,
1716 Chestnut Street,
Philadelphia, Pa.

One Member Re-elected

EDWARD S. CLINCH, JR.,
Consulting Engineer,
116 West 39th Street,
New York, N. Y.

One Associate Member Re-elected

MRS. MARY HALLOCK GREENEWALT,
1424 Master Street,
Philadelphia, Pa.

The General Secretary reported the following change in membership:—

One Member Deceased

FREDERICK D. ADAMS,
Secretary and Treasurer,
The United Illuminating Co.,
128 Temple Street,
New Haven, Conn.

Two Associate Members Deceased

HENRY M. LEVYLIER, Buenos Aires,
Argentine Republic, South America

LEON H. SCHERCK,
Central Hudson Gas & Electric Co.,
Poughkeepsie, New York

CONFIRMATION OF APPOINTMENTS

The appointments of the following chairmen and committee members were confirmed:

Committee on Research

Dr. Louis Bell
Dr. Knight Dunlap
Mr. M. Luckiesh
Dr. C. H. Sharp
Dr. L. T. Troland
Dr. W. T. Bovie (Advisory Member)
Dr. Wm. Duane (Advisory Member)
Dr. E. N. Harvey (Advisory Member)
Dr. C. A. Skinner (Advisory Member)
Dr. F. N. Verhoeff (Advisory Member)

Committee on Editing and Publication

Allen M. Perry

Committee on Membership

H. F. Wallace
E. W. Spitz
Herman Plaut

Committee on Education

L. A. S. Wood

As Members of Sub-Committee on Education in the Public Schools

J. A. Hoeveler
F. M. Wicks
F. J. McGuire
Mrs. Winifred Hathaway

As Member of the Sub-Committee on Extension Course

Frederic A. DeLay

Committee on Papers

Earl A. Anderson

Committee on Artistic Treatment of Interior Lighting

Miss Gertrude Shearer
Herman Plaut
J. L. Stair
Bassett Jones
S. G. Hibben
A. L. Powell
W. T. Blackwell
R. H. Maurer

COMMITTEE APPOINTMENTS:

Committee on Section and Chapter Development

D. McFarlan Moore, Chairman

As Member of the Committee on Residence Lighting by Gas

J. B. Myers

As Members of the Committee on Time and Place of 1922 Convention

H. F. Wallace
F. M. Feiker
J. J. Kirk
D. McFarlan Moore
Walton Forstall, Chairman

OFFICIAL REPRESENTATIVES TO OTHER ORGANIZATIONS:

On U. S. National Committee of International Commission on Illumination

L. B. Marks
P. S. Millar

On American Institute of Electrical Engineers Standards Committee

Clayton H. Sharp

On Governing Board of American Association for the Advancement of Science

Clayton H. Sharp
E. F. Nichols

On the Advisory Committee, Engineering Division, National Research Council

Edward P. Hyde

On the Fixture Manufacturers Committee to Prepare a Code of Fixture Design

M. Luckiesh

REVISION OF THE CODE OF LIGHTING SCHOOL BUILDINGS—The Council moved to authorize the Committee on Lighting Legislation to proceed with the revision of the Code of Lighting School Buildings.

NEWS ITEMS.

Code of Lighting Approved

The "Code of Lighting, Factories, Mills and other Work Places" has been officially approved by the American Engineering Standards Committee as "American Standard," the official date of approval being Dec. 31, 1921.

General Office

As there have been many inquiries for the "Code of Lighting School Buildings," a new edition of the code as issued in 1918 will be printed at once.

Reprints of the "Code of Lighting, Factories, Mills and other Work Places" as published in the November 20th issue can be obtained from the General Office. There has been incorporated in the pamphlet a table of contents and an index.

Copies of the following issues are desired:

Vol. XV, No. 7, Oct. 10, 1920
Vol. XVI, No. 3, April 30, 1921

The General Office will pay fifty cents each for copies in good condition of these issues.

ILLUMINATION INDEX.

PREPARED BY THE COMMITTEE ON PROGRESS

An index of reference to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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TRANSACTIONS
OF THE
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PART II -- PAPERS

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GAS LIGHTING, PAST, PRESENT AND FUTURE.*

BY HOWARD LYON.[1]

The world seems suddenly to have come to a parting of the ways in matters political and moral and in its attitude toward the use of the stored energy of the earth.

Yesterday, the habit was prodigality. To-day the slogan is conserve, conserve. As members of the Illuminating Engineering Society, we are deeply concerned in all problems of light, its economical production, its intensity for specific tasks, its distribution, its direction, its color, its esthetic and hygienic effects and every sort of problem to which light is applied.

At present, light is produced most wastefully. No matter how produced the thing which is mainly produced is heat and only a fragment comes to us as light. From the coal pile to light, the bulk of the coal pile goes to heat and a part which I may speak of as the dust appears to us as light.

There are those who are dreaming of producing light directly by the transformation of energy but it is only the humble fire-fly that seems to have succeeded in that remarkable problem.

A phase of the changing situation as far as conservation is concerned is the tendency toward the production of a different type of gas, of illuminating gas, than that with which we have been familiar. It has been the custom through a long series of years to rate gas according to its candlepower. The new rating asked for by the producers of gas is a thermo-power rating based on the British thermal unit. Just as we speak of a quantity of sugar or water—so many pounds of sugar or so many pints of water; so we may speak perfectly definitely of such and such a quantity

* A paper presented before a meeting of the York Section of the Illuminating Engineering Society, December 9, 1920.

[1] Dr. Howard Lyon, of the Welsbach Company.

of heat. The unit quantity of heat is that required to raise the temperature of a pound of water one degree Fahrenheit, and is generally briefly designated by B. t. u., the British thermal unit.

The gas company has found in consequence of what has become now really a scarcity of oil, that oil is too expensive to put into water gas for enrichment to give high candlepower. Possibly the producers of gas could put materials derived from coal into what is known as blue water gas—water gas without the enrichment of oil—and get a satisfactory number of heat units, at a less expense than that incurred in putting oil into the gas.

In the course of my discussion, it is my purpose to make clear to those not technically trained, the nature of the problems involved in these questions.

PROPERTIES OF GAS.

In the production of light in the past, it has been customary to burn gas in an open flame burner and to produce light by the incandescence of the free particles of the carbon in the gas. If water gas is not enriched with oil, it does not free particles of carbon in such a way as to give light. In fact, this change in composition marks the passing of the open flame burner as a source of light, but this is a case in which both producer and consumer are greatly benefitted. The producer can make some other type of gas cheaper. The consumer is driven to the use of gas through the Bunsen flame and the mantle, and obtains six times the efficiency he can possibly obtain with the open flame burner. Such a change would be of definite advantage to both the producer and the consumer.

In the production of light through the agency of the Bunsen burner and mantle, many difficulties are encountered. These difficulties are due to the fact that the energy, gas, is not standardized. It may differ in composition and in pressure. Such differences may occur from city to city or they may occur within the same city. They may occur within the successive hours of the day or days of the week or months of the year. There is an ever changing pressure and composition of the gas.

Anyone with elementary understanding of physical appliances can see that the device which works under one condition will not work the same under conditions totally or partially different.

When the composition of gas changes, there is involved a change in its power of entrainment, in the amount of air necessary to complete its combustion, in its heat unit value. All of these factors affect the volume of a flame and the volume of the flame must be suited to the mantle or the mantle to the volume of the flame. With a specific mantle the flame must be suited to that mantle so that the final burning shall take place as closely as possible within the meshes of the mantle.

A change of pressure, too, causes a change in the amount of entrainment and consequently in the flame volume. These difficulties have been met in the past by provisions in the device itself for adjustment to changes in composition and gas pressure, or they have been met by not being met. The burner has been permitted to operate with poor efficiency. The efficiency of a gas for the purpose of heating is directly related to its heat unit value; 570 B. t. u. value means a definite heating power for cooking and various processes in which heating is involved.

Another consideration comes in when gas is applied to the production of light, namely, the flame temperature of the gas. The flame temperature of gas is a function of two things; first, the quantity of heat present; secondly, the heat absorbed in raising the products of combustion up to the final temperature.

Gases differ very materially in the quantity of air required to complete combustion and very materially in the quantity of the products whose temperature must be raised to some higher temperature, beginning with the temperature of the air.

I can illustrate the relations that exist between the heat unit value and the flame temperature by naming certain properties of well-known constituents of illuminating gas. I am going to select for my illustration, marsh gas; the chemist will understand it as CH_4; carbon monoxide, which he will understand as CO; hydrogen and benzine vapor. The last named is not present in gas in any large proportion and in cold weather it is condensed. In the warm weather it begins to be free. Considering these gases in order, marsh gas, carbon monoxide, hydrogen and benzine vapor, the quantity of heat that will be yielded by burning one cubic foot will indicate how many pounds of water could be heated one degree as follows, in B. t. u.:

For marsh gas, the value is 919.
For carbon monoxide, about 330.
For hydrogen, about 272.
For benzine vapor, about 3,574.

These values are given to show you that the heat unit value may be definitely and decidedly different.

The flame temperatures of these same gases vary as 1, 1.14, 1.06 and 1.09. One might naturally think that 1, 1.14, 1.06 and 1.09 are pretty nearly the same quantities and they do not seem to be very different. Later on, when I discuss mantles, I will show that even such slight differences must be considered, for they are of much importance.

It is unfortunate for combustion that the oxygen of the atmosphere has to be associated with so much nitrogen. Nitrogen is always a drag on flame temperature. For every volume of oxygen that enters a burner, four volumes of nitrogen are dragged along and distinctly effect a lowering of the temperature of the flame. It is also true that where one of the products of combustion is water vapor, it reduces the flame temperature on account of its high heat absorbing capacity.

However, nitrogen, water vapor and carbon dioxide are present in the products of combustion and their temperature must be raised to the final temperature. Flame temperature then, depends on two factors—the heat unit value and absorption by the products of combustion.

It will be noted that the number given for benzine vapor, as its heat unit value, 3,574, is more than ten times the value given for carbon monoxide. Notwithstanding that fact, the flame temperature of carbon monoxide exceeds that of benzine vapor. The carbon monoxide flame is actually a hotter flame—a very important consideration as will be shown later.

One of the changes that has been proposed by the gas companies is the production of what is known as blue water gas, which is composed mainly of carbon monoxide and hydrogen in somewhat nearly equal parts, constituting 95 per cent. of the gas, this being mixed with a coal gas to bring its heat unit value up to a certain standard.

After people become familiar with the fact, they would be quite satisfied to purchase gas according to its heat unit content, but at present, there is no widespread knowledge concerning the meaning of the heating value of the gas.

THE GAS MANTLE.

Before explaining the significance of flame temperature, it will be necessary to discuss the mantle briefly. The mantle is a very wonderful structure. Perhaps as great skill, chemical, physical and mechanical, has been exercised in the manufacture of mantles as in any commercial product known to us.

About 35 or 36 years ago, Karl Auer, an Austrian, in Vienna, was making some experiments on bodies that we call rare earths. He was studying the spectrum of the element erbium in the form of erbium oxide. He conceived the idea of saturating a cotton thread with a salt of erbium and then burning off the fabric of the thread thus securing some of the material in form to introduce into a flame for his spectral study. To his very great astonishment, he found that when the material of the thread burned off, the erbia ash, repeated in all its structure to the minutest detail the fibers of the thread. This led him to wonder whether other rare earths in general had these characteristics. He began to investigate and found that that was a common characteristic, namely, that bodies of the rare earth group did form a coherent ash.

The materials that are used for the cylindrical webs of commercial mantles are sometimes cotton, sometimes what is known as artificial silk, and sometimes of ramie, which is a China grass. Artificial silk as known to the trade is dissolved cellulose formed into rod fibers.

Dr. Auer, who is known now as Baron Von Welsbach, conceived the idea from his experiments with rare earths that it would be possible to weave cotton in the form of a cylindrical web, to saturate it with the rare earths, and then to burn off the cotton fabric and have a cylinder or cone that could be placed over a Bunsen flame and be made a source of light. He had already noted that the oxide of the rare earth when introduced into the flame glowed with great brilliancy and he did actually show the processes of making the earlier mantles, but they were com-

posed of materials that we know as ceria, lanthana, and zirconia. These mantles were sold to the public but they were very unsatisfactory. They were not durable. They became fragile under the influence of such atmospheric elements as carbon dioxide and water vapor, very much as lime slakes when exposed to the atmosphere. The business of mantle making was not very prosperous while mantles were composed of these materials.

Dr. Auer attacked the problem of making a better selection and his effort finally resulted in the selection of two of the oxides of the rare earth, ceria and thoria, in the proportion of 1 per cent. of the former to 99 per cent. of the latter. Mantles of that composition are made and universally used throughout the world to-day. No better composition has been found and we may fairly say no better composition is in sight than that consisting of 1 per cent. cerium oxide and 99 per cent. thorium oxide.

What is the significance of this peculiar and particular combination of these oxides of the rare earths? A real mathematician and physicist might give you some very long equations and might make them quite confusing, but I am going to make it so simple that all may understand. Keeping in mind the composition of the mantle, I will state the function of the two materials introduced into the mantle and state why they give such an abundance of light when heated in the Bunsen flame.

When thorium oxide is heated alone in a flame, it gets very hot, closely approaching the temperature of the flame, because it is so constituted that it does not radiate its energy freely. It is one of the few things that may attain a very high temperature in the flame because of this characteristic. Thoria would not make a good mantle, nevertheless, because it does not happen to radiate its energy in the form of light. It would be a very poor light giver.

On the other hand, cerium oxide when heated alone, being a very good radiator, does not attain a high temperature. Therefore, cerium oxide alone would not make a good mantle. If by any means cerium oxide be heated to a temperature corresponding to that which thorium oxide attains in the flame, it gives off a flood of light. It radiates efficiently only at a high temperature.

The problem was or is, how to heat cerium oxide to a high temperature or to a sufficiently high temperature to make it an

efficient light radiator. The method is exceedingly simple. A very small portion, 1 per cent. of cerium oxide, is combined with a very large amount, 99 per cent. of thorium oxide. Thorium oxide nearly attains the high temperature of the flame and heats up the small portion of cerium oxide. At that high temperature, the cerium oxide is an efficient radiator of light.

Simply stated this is the theory of this particular composition. It might occur to one that if we increased the quantity of cerium oxide we would secure better results. No, because in that case, we would pull down the temperature of the flame and it would not radiate light efficiently. One might think that the output of light might be increased by diminishing the cerium oxide. That would not do, because when we passed a certain limit there would not be enough cerium oxide to radiate. Hence there is a critical composition in a mantle in the percentage of cerium and thorium oxide.

There is also a critical weight of a mantle per unit of surface. If a mantle is made very light, it glows very brilliantly, but it is too fragile. If it is made too heavy it cannot be heated hot enough to radiate efficiently. This result corresponds to the well-known fact that a very small quantity of heat cannot heat materially a quart of water, but that same quantity of heat applied to a drop of water will bring it to the boiling point. The same heat energy problem prevails in regard to a mantle.

The significance of flame temperature as applied to efficiency of light production in mantles is not difficult to understand. Marsh gas has a flame temperature which is represented by 1, and carbon monoxide a flame temperature which is represented by 1.14. Those numbers do not seem to be very different and their significance does not seem to be very great, but a remarkable fact is that near the temperature which a mantle acquires in a flame, the efficiency of light production does not vary as the flame temperature, or in this case as 1 to 1.14, but as these numbers raised to the 11th power. One raised to the 11th power is 1, but 1.14 raised to the 11th power is the quantity 4.2.

The interpretation of these results is that if the same number of heat units be supplied to a mantle, first using marsh gas, and secondly, carbon monoxide, the resulting light efficiency of the two would vary as 1 to 4.2. There is thus an enormous increase

of light with a certain slight change of flame temperature. Now, if the gas company were to furnish entirely blue water gas for lighting purposes, and they were willing to supply 2 cu. ft. of it for 1 of carburetted water gas, the consumer would have about the same number of heat units, but the flame temperature of the blue water gas would be relatively about 1.016, which is a very small increase, but on the basis of the 11th power of 1.016 a non-carburetted water gas or blue gas would give 20 per cent. greater efficiency than marsh gas, provided that the same number of heat units were supplied. All of these are problems of mathematical precision.

In any gas lighting device one may increase the efficiency of light output very materially by increasing the entrainment of air. Increased entrainment of air means a condition that permits passing a greater number of heat units per unit of time through a square unit of surface of the mantle than when the entrainment is low.

One of the first objects that is sought in the construction of gas burners for producing light through the agency of the mantle is to increase if possible, the amount of entrainment which the burner is able to effect. By increasing the entrainment there is delivered into the meshes of the mantle a greater number of heat units and more gas is burned within the meshes of the mantle in a unit of time than would otherwise be possible.

The position of the mantle with reference to the flame has a most important bearing upon the light output. The mantle should so be positioned that the final combustion will occur within the meshes of the mantle.

Before passing entirely the subject of mantles, it is well to mention the importance of the purity of the materials entering into the mantle structure. The cotton used in weaving the web from which the mantle is made is treated in such a way as to have as high a degree of purity as it is possible to attain. I think it contains about one-quarter the quantity of impurities in any form that is contained in the absorbent cotton that is supposed to be remarkably pure. It goes without saying that any particle of dust, anything other than cerium and thorium oxides in the mantle will have a very detrimental effect upon the light-giving power. The workers in the factory who handle the mantles must

work with clean hands and the room must be clean. The chemicals and the webbing must be clean. In all the processes of cleaning webbing, tons and tons of distilled water are involved, and in some of the processes even the air coming into the room is purified by being sprayed with water before it is admitted.

Purity is the watchword all through the mantle processes and I think no more careful attention has been given to the chemistry of any product than is given to that of a gas mantle.

THE GAS BURNER.

As is well known, the first object in the construction of a device for giving light through the agency of the Bunsen flame and the mantle is that the device itself be dependable, reliable. It must give no trouble to the user. Much attention has been given to that matter, as well as to the features of the burner that make for increased entrainment. It goes without saying that the orifice from which the gas comes as a fine stream must be straight so that the stream includes the axis of the tube beyond; if it does not go straight the entrainment is not perfect.

There is generally some sort of mechanism by which the gas stream may be controlled as the pressure increases or diminishes or the gas changes in composition due to the non-standardization of the gas.

From the orifice, gas issues into a tube of some width, which has openings to admit the air from the atmosphere. Generally these openings are controlled by an air shutter, by turning which the amount of air that enters may be varied. This tube gradually narrows down to a certain diameter at the so-called "constriction" point. It makes a great deal of difference where that constriction begins as a real constriction, that is, how far away from the point of the issuing gas. It also makes a great deal of difference whether that constriction bears some definite relation in diameter to the gas stream. In the design of the burner all such matters are attended to with great care.

Beyond the constricted portion, the tube again widens to conform with the stream lines of the gas. The widening of the tube at some specific and definite angle furthers the passing of the gas through the tube with the minimum of friction. A commercial burner, viewed casually appears as though someone had con-

ceived of it as being of a pretty shape, but back of that shape, pretty or otherwise, is some foundation of principle. Beyond the widened portion and in the burner head, attention is still given to the stream lines so that there shall not be eddies in the course of the flow. When all these things are attended to, the air is entrained in larger and larger proportions to the volume of the gas that is passing through.

Somewhere in the structure of a burner there must be something equivalent to a piece of wire gauze to prevent "back fire," as the action is termed. At the moment of turning on the gas and later, there may be a back fire or explosion which will shatter a mantle. Somewhere within the structure is introduced a bit of gauze, its purpose being the same as that of the gauze in the miner's lamp, namely, to lower the temperature of the mixture so that ignition will not spread further than just to the gauze.

When gas is turned into a burner there is not only the air that is entrained in the air ports but also that which was present in the burner tube. There may be such a proportion of air at the outset as to form an explosive mixture.

In turning off gas supply, the loss of velocity of the issuing gas may result in an explosion. Two forces are always at work. The first is the translational velocity of the gas out from the burner nozzle and the second is the velocity with which the explosion spreads through the mixture of air and gas back towards the burner.

The flame is the resultant shape of the zone where those two forces or velocities are balanced, the onward motion of the gas and the backward explosition as the combustion takes place.

I have given, as I have intended, a good deal of theory in as simple a form as I have been able to command and the hard headed ones among you will say: "What is the use of this? What does it amount to?"

Well, we that are closer to the matter than you, see that it is all important. Considering one of the features that I have spoken of, increased entrainment, what does it mean? What does it signify? What does it amount to? Well, just this. If a burner entrains or draws in at the air port 2.5 volumes of air to one of gas or less, one cannot secure satisfactory incandescence of a mantle or a good output of light from a mantle unless it be sur-

rounded with chimneys or cylinders. (This remark applies to carburetted water gas or to coal gas of recent years.) Until within the last very few years, almost all devices for giving illumination through the burner and mantle were provided with chimneys.

What objection is there to chimneys? Why just the objection of great bulk. Until within very recent years, burners had to be provided with chimneys to give a satisfactory output of light. By increasing the entrainment to four volumes of air to one of gas, one is able to dispense with chimneys, and this very materially tends to diminish the bulk of the burner structure and permits artistic surroundings or housing for the lighting device. To the layman, it obliterates the lighting device and all he sees is the light through an attractive housing. Even though a burner operates without a chimney or cylinder, there is a brilliant incandescence of the mantle.

Thus, the breakage of glassware is eliminated and the structure can be concealed within the bowl. When the fixture is hung, one sees no part of the burner structure at all. One of the arms serves as the conductor of the gas down to the burner structure. In the various smaller units, compactness of structure is due to the fact that one need not surround the burners with close fitting glassware. Glassware may be used for artistic purposes or to cut off the intense glare of a mantle surface, but it is not needed at all to make the lamp a more efficient light giver. It is simply an ornament, as is the case with a lady's hat—not absolutely necessary, but giving an attractive appearance.

Another very important result of increased entrainment aside from those mentioned, namely, the elimination of glassware, concealment of the device and artistic housing, is the increase in specific brightness of a mantle surface.

By paying attention to the stream lines of burner passages there is secured another important possibility, namely, that of shortening the Bunsen tube or burner structure. In some early mantle lamps that had very long burner tubes, it was impossible to make an artistic structure, but with the shortening of the tubes, compact and artistic structures are possible. Furthermore, attention to the stream line of passages makes the devices capable of

operating with some degree of satisfaction under varying conditions. It makes a more flexible device and adapts it better to changing conditions of gas pressure and quality.

The principles involved in the incandescent gas lamp are attractive from a scientific standpoint and have resulted in artistic structures that have contributed in countless numbers to the comfort of the home.

DISCUSSION.

The above paper was discussed simultaneously with that of R. H. Maurer, "The Testing of Gas Lamps." See page 18.

THE TESTING OF GAS LAMPS.*

BY R. H. MAURER.[1]

The purpose of this paper is to explain why and how gas lamps are tested by the Consolidated Gas Company of New York, and the value of such testing from both the commercial and the illuminating engineering standpoint.

One aim of the Illuminating Engineering Society is to better lighting conditions throughout the country. This is a gigantic task and can be accomplished only by the hearty cooperation of all interested in lighting, be it gas, electric or oil, and especially of those engaged in the commercial effort who can best help to carry the good work to the public. In order to promote the proper use of light it is necessary to equip these missionaries with proper data so that when they go out to sell lighting, be it units or service, they can talk intelligently on the subject.

How much easier it would be to sell a particular lighting unit, for instance, if the salesperson could tell the prospective customer that the unit in question would give a certain candlepower or illumination when placed in the room in question, how many such units would be required, the operating cost of the same and the effect of various colored walls and ceilings, etc., and how money could be saved by planning the lighting installation along certain lines and placing the outlets to the best advantage.

Unfortunately, there are numerous irresponsible retailers and house to house peddlers whom we can hardly hope to reach in our effort to educate, and who, I believe, are responsible for most of the lighting atrocities which we find to-day. The only way to improve this condition is by spreading propaganda through the public utilities and other responsible lighting organizations to such an extent that the general public obtains some idea of the benefits to be derived from following our advice so they will eventually demand that their lighting equipment be installed in accordance with good practice.

If all lighting service companies and others interested in selling lighting equipment would insist upon selling only the units which

* A paper presented before a meeting of the New York Section of the Illuminating Engineering Society, December 9, 1920.

[1] R. H. Maurer, Illuminating Engineer, Consolidated Gas Company of New York.

have been tested and proven safe, efficient and satisfactory from an aesthetic and illuminating engineering standpoint, much of our present bad lighting would be eliminated.

In our own company it has been found necessary and ultimately profitable, to instruct those engaged in the selling of lighting units in the general requirements of good illumination. We are convinced that selling lighting fixtures, lamps and accessories, under these conditions, will prove better for both the seller and the buyer, than if the salesperson does not know the rudiments of correct illumination.

In order to secure illumination data, it is necessary to test many lamps, mantles, glassware and accessories. There are, however, many subjects such as glare, effect of colored walls, ceilings, hangings and other aesthetic considerations which do not come under the subject of this paper. Our chief concern in testing lamps is to secure the most efficient unit, and after we have done this our next step is to equip that unit with proper shading or reflecting media and to gather such data as will help in laying out a lighting installation using the lamps approved.

The testing of gas lamps is carried on in our laboratory somewhat in the following manner, and from the results obtained from these tests the lamps are approved or not approved for the use of the company.

For convenience in testing, gas lamps are classified in the following manner:

Upright Mantle Units—Domestic
Commercial
Industrial
Inverted Mantle Units—Domestic
Commercial
Industrial

When a lamp is received for investigation, it first undergoes a rigid physical examination, that is, it is examined for safety, workmanship and construction, weak points are noted and if these points can be easily adjusted the manufacturer is informed and the changes are made. If, on the other hand, the lamp would have to undergo a complete reconstruction to meet our requirements, the unit is not tested, but is sent back to the manufacturer with a statement of our objections, and he is at liberty to make a new unit and submit it for consideration.

RADIAL PHOTOMETER ROOM.

In Fig. 1 is shown the radial photometer room. This room is finished completely in dull black. The radial photometer consists of a 3-meter bar photometer, using an electric standard or pentane standard lamp. Use is made of a Luhmer-Brodhun disc and sight box. The main feature of this photometer is the rotating head which is equipped with two mirrors and revolves on a circular track, the degrees being calibrated on the circular head.

The gas lighting unit to be tested is hung on an adjustable iron tripod and can be readily adjusted to any position desired by the aid of a swivel joint specially constructed for this purpose.

The electric current used for the standard lamp is taken from a battery of 74 storage cells of two volts each. The current is controlled and measured for this lamp by the use of a potentiometer and galvanometer. A novel feature of the battery room is that any combination of voltages desired from 2 volts to 150 volts can be obtained. This is made possible by arranging the cells in four sections of 13 cells each, with 22 end-cells separately connected to the switch board.

METHOD OF TEST.

The lamp is examined for the simplest method of adjustment, that is, (*a*) gas adjustment only; (*b*) air adjustment only; (*c*) gas and air adjustment.

The test begins by determining the candlepower distribution in a vertical plane with the lamp new, equipped as placed on the market, or with special equipment covered by the assignment. The initial distribution test is performed with stored gas which enables the test to run over until the next day with very little change in the heat-unit value of the gas. Two 75-cu. ft. holders are used for this purpose.

After the simplest adjustment is made, the lamp is set on the photometer and the mantles supplied with the lamp are put in place and burned off, each mantle being lighted from the top. The glassware is cleaned or use is made of a cylinder, unless the lamp is of a type that requires an outside globe, or the assignment specifically requires the test to be made with certain glassware equipment. The lamp is then adjusted to approximately the maximum light output, and the mantle is burned for half an hour in

order to maintain an even temperature for the burner. After this burning the lamp is adjusted by the use of the radial photometer to its best efficiency or maximum candlepower combined with minimum gas and air supply. The photometric readings are taken at the 90° position for the upright lamps and 75° position for the inverted lamps. I might say here that the maximum candlepower for upright mantles without enclosing glassware is found nearly always at the 90° position, and that for the inverted mantles at the 75° position.

In order to find the average position which is fair for the lamp on test, the candlepower of the lamp is taken at six equidistant asimuths, at the 90° position for upright and at 75° position for the inverted lamps, the nadir position being at 0°. The mean position for the lamp for photometering is determined from these figures, so that it will be possible to duplicate the position after the lamp has been taken into the life test room.

RESULTS OF TESTS.

The data for the candlepower distribution curve is determined from an average of several readings taken at each 10° position. The calorific value, specific gravity, consumption, pressure and temperature of gas, together with atmospheric conditions are noted. The temperature of various parts of the lamp, especially those likely to be handled, and the behavior of the lamp in general are also noted.

Tests of candlepower distribution are run at all gas pressures from 15/10 in. to 45/10 in. of water column for low-pressure units and from 1.5 lb. to 3.5 lb. for high-pressure units, the lamp being given an average adjustment with minimum attendant gas consumption at each pressure.

A curve of pressures and the mean spherical candlepower is drawn and the pressure corresponding to the maximum mean spherical candlepower is noted. The values at various pressures are taken from the candlepower distribution tests at these pressures.

In order to determine the variation in efficiency and in candlepower of the lamp with small changes in consumption, gas is supplied at the above determined maximum mean spherical candlepower pressure. Several eye adjustments are made so as to vary

Part II 16a

Fig. 1.—Radial Photometer Room.

Fig. 2.—Life Test Room, where mantles and lamps are tested.

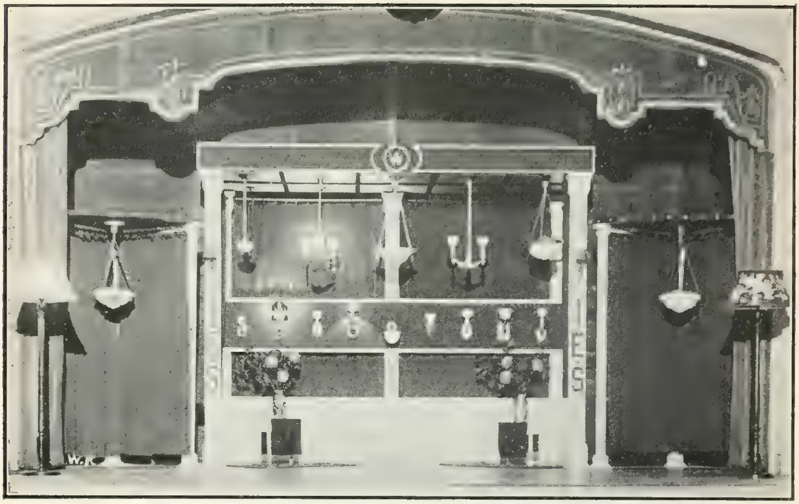

Fig. 3—View of the gas-lamp exhibit taken by the normal light of the auditorium.

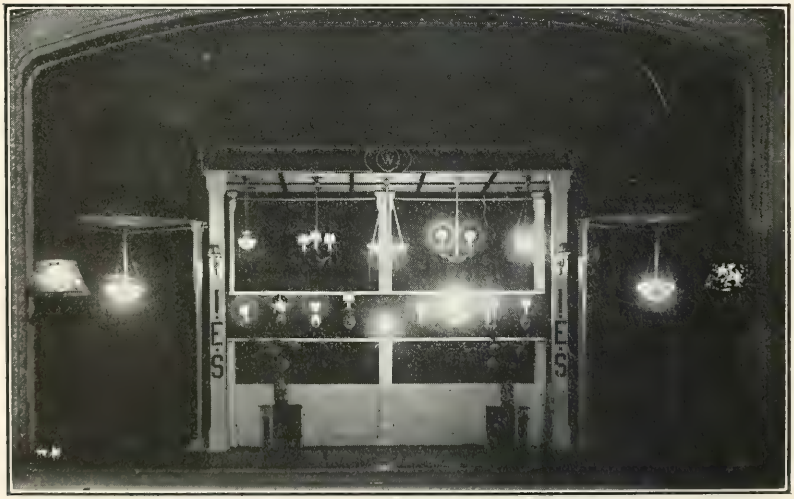

Fig. 4.—Gas-lamp exhibit with auditorium darkened.

In connection with the presentation and discussion of the papers by Messrs. Lyon and Maurer, there was arranged by Mr. F. R. Barnitz, assistant secretary of the Consolidated Gas Company, in this company's building where the meeting was held, the exhibit of gas lamps shown in the above illustrations. On the stage in show-window style there were hung various types of side-wall and ceiling fixtures equipped with various vertical and inverted mantles. On either side were mounted the letters I. E. S. finished in gold. In two smaller supplementary booths, one on each side, were displayed the new semi-indirect units. Gas floor lamps of a handsome design were placed to the right and left of the stage, and also at the entrances at the rear of the hall.

the consumption on both sides of that corresponding to the maximum candlepower, the gas consumption and candlepower data being noted.

Curves are then plotted showing the correct consumption and pressure. The mantles are then changed for the mantles of the definite unit, weight of ash and saturation known as the standard mantles, against which the original mantles are compared after having been burned on the life rack.

In order to duplicate the conditions found in actual practice the lamp is then removed to the life room, shown in Fig. 2, or if outdoor units they are moved to an outdoor life rack. The units are operated for a maintenance period at standard service pressure of 25/10 in. of water column, and allowed to burn for five hours each day. During the maintenance period, usually 100 hours, notes are made of the operation and behavior of the lamp, mantle or globe breakage, popping, flashing (especially at ignition), carbonization, whistling or roaring and other information and incidents of interest, and changes are suggested to the manufacturer to overcome any defects.

At the end of the maintenance period, the lamp is removed bodily and replaced on the 3-meter photometer and the candlepower distribution is again noted at 25/10 in. gas pressure, with the test mantles and with standard mantles. The total deterioration of the unit as a lamp is thus measured. The glassware is cleaned, replaced and further candlepower distribution readings are taken with both the supplied and the standard mantles, under conditions as closely approximating the original as possible. The losses due to the dirt accumulation on glassware, and the accumulation in lamp proper and the mantle deterioration can be computed from these data.

If the lamp shows decided promise and efficiency a life test is made. The lamp is put back on the life rack, and using the test mantles, it is allowed to burn for a period of from 1,000 to 2,000 hours at the standard pressure, and the same procedure is followed as above. During this burning, the lamps are inspected daily and notes are made on the operation, as well as the number of adjustments necessary.

From the results of our tests we obtain the following information which is of value to the commercial department and the illuminating engineer:

(*a*) The efficiency of the lamp—rated in lumens per heat unit (B. t. u.) per hour.

(*b*) The gas consumption at all pressures and the maximum candlepower in any particular direction.

(*c*) The absorption by enclosing glassware.

(*d*) The depreciation due to dirt, dust, etc.

(*e*) The life of the lamp and mantles under average district use, thus being enabled to judge the number of maintenance calls necessary.

(*f*) The cost per hour in energy used and many other items of interest which are derived from the foregoing tests, and are put in readable form for the persons interested in selling and in the engineering departments of the company.

DISCUSSION.

The papers by Messrs. Lyon and Mauer were discussed together.

CHAIRMAN MYERS: Dr. Lyon neglected to mention one little point that ought to be brought out, and that is that the development of the new burner described by him is due to the efforts of his laboratories. The electric lamp testing men in the room, having listened to the reading of Mr. Mauer's paper, will agree with me that not all of the details regarding measurements are located in our end of the business, but that the gas men also cover the details equally well.

H. V. BOZELL: What has been the progress in the control of the quality of the light produced by the gas mantles. There used to be a good deal of green, for example.

HOWARD LYON: It is possible to control the color of the light through a quite considerable range, by varying the quantity of cerium oxide in relation to the thorium oxide, not giving equal efficiency in quantity of light but giving a wide range of color just by varying the quantity of thorium oxide.

MR. HAYDEN: May I ask Dr. Lyon to say something about high-pressure lighting as used in European countries?

HOWARD LYON: I cannot explain why high-pressure lighting has not been employed more extensively in this country than it has. Perhaps it is due to the mechanical trouble involved in producing high-pressure gas. There is another result in high-pressure lighting which we know, but which Europeans may not consider as vital, and that is that in high-pressure lighting, the temperature goes up very materially and that means in time and a rather brief time, the volatilization of the cerium oxide and loss of efficiency of the mantle. Of course, some of that same difficulty is encountered in constructing burners for maximum high entrainment at low pressures. High pressure means pounds, while low pressure means ounces in pressure. At low pressure one may proceed to a certain degree without the deterioration of the mantle, due to the very high temperature to which it is subjected in the lamp. However, the European countries do use gas with very fine results and seem satisfied. To be perfectly frank, they are more careful about the expense of lighting than we are in America. Here if a certain result may be secured, brilliant, attractive, why, we are willing to go to the expense and to lavish money upon it. I suppose that there is nothing anywhere in Europe to compare with our waste in lighting every night in New York City, waste as far as economy is concerned, in sign lighting and in the very brilliant illumination of show windows, and so forth. It is an American habit to be willing to lavish money.

H. V. BOZELL: Dr. Lyon has brought up the subject of economy which causes me to ask another question with reference to the operating costs of these new units which open up new developments—open up new possibilities for illumination—as to what the relative operating cost of these are, that is to say, the actual operating costs. A comparison might be made with that with which many people are more familiar—the cost of a certain amount of light produced by electricity; it appears to me that this newly developed fixture opens up a new field in lighting of certain kinds. I understand that the records of recent sales of the New York Consolidated Gas Company of this semi-direct type of fixture represents quite an extension of this type of illumination.

HOWARD LYON: Every sort of improvement to which I have referred results in reduction of the cost of producing light—every one of every description. However, do not be confused. As they see it can be produced more and more economically, people seem to want more and more light and I presume as time goes on they are paying more and more for light. Probably that is true in the electric field as well as in that employing gas. People are tempted by the brilliancy of the results to use more and more light. Every stage of development that I have explained results in actual economy of light production.

RALPH E. MYERS: Is there any relation between the air entrainment in the burner and the flashing back of the flame? Do variations in the entrainment affect the flame's stability?

HOWARD LYON: In general, yes. Increasing the amount of air entrainment leads to more care in preventing the back firing on lighting or extinguishing. It leads to the use of burner tubes and passages that conform to stream lines of the gas, and demands more attention to the gauze that is introduced into the burner. Such provisions make back-firing a controllable thing.

RALPH E. MYERS: Have tests been made as to the lumens output per heat unit input for the new lamp?

R. H. MAUER: The Consolidated Gas Company has not tested the late mantle which is called the "thrift" mantle, and hence we have no figures on the lumens per heat unit. This is a newly-developed mantle and the figures are not available yet. I can't tell the figures that we have from actual test, but perhaps Dr. Lyon can give some further information. They may have made some tests.

H. V. BOZELL: What is the gas consumption on some of these burners?

R. H. MAUER: On the small c. e. z. burner, which Dr. Lyon described, the consumption is about 3 cu. ft. per hour. On the "thrift" burner the consumption, I think, is about 2.5 cu. ft. per hour, and on the "junior" mantle about 2.5. The "junior" mantle

has been used quite extensively. It is enclosed by a small mica cylinder and apparently gives a little more light than does the "thrift." The horizontal candlepower of the "junior" runs about 60 cp. and the "thrift" I think will run in the neighborhood of 35 or 40 cp. The "thrift" burner, as I understand it, was made chiefly to take the place of the open-flame burner, giving much larger candlepower but reducing the consumption to from one-half to one-third. The open-flame burners are marked for 4, 5, 6, 7, and 8 cu. ft. per hour and many burn more gas. The "thrift" burner has a consumption of 2.5 cu. ft. per hour, and gives twice as much light as the No. 5 open-flame burner. The open-flame burner now does not give much light, and people will have to use some other means of illumination. This would be satisfactory to the gas company and very beneficial to the consumer, as it would stop the unnecessary waste of gas.

H. V. Bozell: To what pressure do the ratings given apply?

R. H. Maurer: The pressure at the laboratory duplicates what is generally found in the district.

Howard Lyon: Concerning the blackening of the mantle, it can be said that with proper entrainment of air, there will be no blackening. Such blackening of the mantles as may be found is due to some defect in the burner which may be a passing one or represent the accumulation of dirt. When the mantle blackens, the hydrogen of the gases separates out and leaves the carbon unconsumed and deposits it on the surface of the mantle. Short of the border of the flame, there is a reducing action, as the air hasn't access to it to burn up the carbon. If, however, the gases can be burned closely within the meshes of the mantle so that the sweep of air can come over the surface there will be no blackening of the mantles. Blackening of mantles, a bogey only a few years ago, has largely disappeared with the newer types of burners.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XVI | MARCH 21, 1921 | NO. 2

THE "REMOVABLE FIXTURE:" ITS SIGNIFICANCE.*

BY O. H. CALDWELL.

To the married men in the audience, who at some time in the past have moved from one place to another, I want to ask the question—what was the first thing the good wife said when she inspected the new house? Wasn't it something like this?

"Oh, those horrid lighting fixtures. I like the house itself, but the lighting fixtures are awful! Can't we have them changed for something more artistic?"

For years past hundreds of thousands of women have been making this self-same complaint, yet lighting fixtures remain to-day the only electrical devices out of the whole list of some 5,000 current-consuming appliances which are still solidly nailed, screwed, bolted and soldered to the building walls and circuits. But why should not lighting fixtures be attachable and detachable as easily and conveniently as we plug in or disconnect an electric iron, percolator or portable lamp—if the ladies want them so?

Lighting fixtures are the electrical decorations of the home; they are the "lighting furniture" of any room. Let us think of them, not as fixed fixtures, but as lighting furniture.

In recent years we electrical men have all been surprised at the tremendous growth in the use of portable lamps. Women are buying portable lamps because they can change them about at will, and adapt such portables to the artistic expression of their own tastes in home decoration, with the aid of baseboard receptacles.

If such receptacles in the baseboard are desirable to make portable lamps easy to connect, why then should we not have properly-

* A paper presented before a meeting of the New York Section of the Illuminating Engineering Society January 13, 1921.

placed similar outlets in the side walls which would permit changing our bracket fixtures when the customer wants new ones. Why not be able to "hang a fixture like a picture?"

And then again, why not have receptacles in the ceiling so that, according to the housewife's taste, she can have ceiling fixtures put in or left out—and change fixtures at will—to harmonize with her scheme of home decoration.

The presence of fixture hanging outlets would make possible the selection of fixtures by experiment to secure desired lighting effects.

The presence of such outlets and fixture connections would make it possible to readjust lighting fixture locations to correspond with furniture rearrangements, without the expense and annoyance of employing an electrician.

Fixtures could be taken down and put away during the summer months, or simpler ones could be installed in their places at the time the linen coverings appear on the furniture and the winter draperies are put away for another season.

Electric fans could be suspended from the outlets in place of the bracket fixtures during the summer months. Every fixture outlet would become a "convenience outlet" for the convenient connection of any electrical device—vacuum sweeper, fan, toaster, etc. Fixtures could easily be taken down to be cleaned, repolished and relacquered, to the householder's satisfaction, besides contributing additional business to the fixture man.

Then there is the great field of "refixturing." Householders who are now living in painful association with lighting fixtures of jarring design and finish, would be willing prospects for the purchase of one or more of the many beautiful lighting-fixture creations that are now obtainable. This refixturing work would open up tremendous new sales opportunities for dealers. At present, however, under many state laws, the landlord can claim anything that cannot be removed without interfering with the wiring or other parts of the house structure, which renders the average tenant very chary of spending money for the benefit of his landlord. Moreover, the resistance which is interposed by the necessity of calling in professional fixture hangers to do a simple job of changing fixtures, and the housewife's distinctive dislike of hav-

ing workmen in the house discourages refixturing under present conditions.

For the manufacturer and jobber this innovation offers the sale of a positively new line of outlet receptacles and plugs, one for each of the four million new fixtures which are hung yearly. At the present time America's building program is 1,300,000 dwellings short and during the next two or three years we shall undoubtedly have some of the most tremendous home building years in the history of the country. If these million-odd new homes can now be equipped with a universal fixture-hanging receptacle, a tremendous impetus will be given to the idea, contributing to its rapid spread to houses already built.

The electrical contractor will benefit in many ways. It will enable him to do a better wiring job, to make profit on the new receptacle item, to save material and labor, to finish his work at one time and to have one instead of two inspections.

It will mean much to the fixture dealer because with "quick attachable" fixture outlets, his outside labor problem will be simplified, more customers will be disposed to buy style fixtures—real lighting furniture that anyone can install. He will win customers' satisfaction, for the new conditions will enable the fixtures to be selected and installed under the actual conditions of the home, and a tremendous field of refixturing sales will be opened up. Fixtures for the first time in lighting history will become articles of merchandise instead of specialties.

Many householders are fussy and hard to please when selecting fixtures because they realize that under present conditions when a fixture is installed it is up permanently. If it were possible to try one or two alternatives in a few minutes there would no longer be such a feeling of finality about the choice and the customer would most likely accept the standard design without a murmur. This feature of standardization of designs would also contribute to the larger sales of fixtures by the wholesale dealer for it would enable him to standardize his line and handle fewer patterns.

Electrical inspection authorities should be pleased with this new arrangement because an approved plug construction would put a workmanlike finish on the job and eliminate that one bad spot in modern wiring—the soldered-and-taped joint beneath the fixture canopy—replacing it with a workmanlike, safe connection

which the inspector would not have to tear open to see if the joint is really soldered. Moreover, in most cases, inspection would be cut down to a single inspection, without a re-inspection at the time the fixtures were added.

The landlords and builders may be expected to encourage this idea because it will save them the expense of fixtures. In the case of ready-built and speculative houses, the fixtures installed by speculative builders are usually of the cheapest quality and are bought direct. When fixture receptacles are available the builder will install only the receptacles, with considerable saving of money to himself, and then the tenant or purchaser will be able to buy from the nearest fixture dealer the kind and quality of fixtures to suit his individual taste.

But above all, we must not forget that it is the great American public with whom we are most concerned in serving when we propose and discuss this change. The public is boss, and whatever will best serve the public, the public will eventually get, regardless of any opposition on the part of any trade group.

With the removable fixture idea applied generally, the family that rents or buys the house will not have to endure fixtures that they do not like. They will be automatically encouraged to buy fixtures to suit their tastes and to change them as often as they like. The way this idea may be expected to appeal to the public is well indicated by the following quotation from an article by Floyd Parsons in the *Saturday Evening Post,* for January 1st. Referring to the plan to "hang a fixture like a picture," he says:

> "At the present time practically all the electrical fixtures hanging from the ceiling or attached to the walls are fastened as solidly in their positions as are the radiators, doors and bath tubs in the house. No idea could be more absurd than that of soldering the joints and making a mess of the wires under the canopies of these fixtures.
>
> "Why should we not standardize the fixture-hanging outlets? Then we could hang a fixture as we now hang a picture. Why not build houses with standardized quick-attachable ceiling and bracket outlets, so that the housewife will be able to change her electrical fixtures as often as she changes her tastes or her furniture? At the present time, when a tenant moves into a house he must be satisfied with the fixtures that are already there, no matter whether or not they harmonize with his furniture designs.
>
> "When a single satisfactory fixture-hanging outlet is placed in all houses it will be possible for the housewife when she moves to take her

favorite fixtures with her to the new house, along with the family beds and bureaus.

"This would take the lighting dealer's wares out of the class of fixtures and make of them what might be termed lighting furniture.

"If a standard outlet receptacle is a good thing in the baseboards of a house, to make portable lamps easy to connect, why is it not a good thing to have standard push-plug receptacles in the side walls and ceilings, so that lighting furniture can be put into place as easily and quickly as a picture is hung, and changed at will to harmonize with the rest of the furniture and decorations in the rooms? There is no more reason why a landlord should select his tenants' electrical fixtures than there is for his selecting a divan for the tenants' living room or a table for the library.

"Standardization saves, simplifies and satisfies."

Practical progress is now being made to put such fixture-hanging fittings on the market. Since the idea was first launched in the electrical press in December, 1919, a number of inventors have appeared with some very ingenious devices.

Of course, it should be understood that the fundamental idea of quick-attachable fixtures is in itself not patentable. The only patents that can possibly be obtained are mere detail patents covering only some detail of the means of mechanical support.

The principal receptacle manufacturers have recognized the importance of agreeing on a single universal standard device. We all know the confusion that has resulted from the 37 different kinds of attachment plugs on the market. No man in this room will question that, if we are to have a lot of different kinds of fixture hangers that are not interchangeable, we had better give up the whole idea and keep on with the present method of soldered and taped joints.

But if all the manufacturers who are about to put on the market devices to "hang a fixture like a picture" will see their responsibility to the public, to the trade, and to their own best interests, and will agree upon a single universal device, not only will they profit far beyond their fondest dreams, but a new era of fixture usefulness will be ushered in for the electrical trade, for the fixture interests and for illuminating engineering generally.

DISCUSSION

The papers by Messrs. Caldwell, Luckiesh, McCoy and Shore were discussed together.

THE "REMOVABLE FIXTURE": ITS RELATION TO BETTER LIGHTING.*

BY M. LUCKIESH.

The chief deterrents to the progress of lighting in residences and in similar fields of lighting are: (1) the general indifference toward lighting on the part of the consumer, the fixture manufacturer, and the fixture dealer; (2) the general lack of appreciation of the potentiality of lighting; (3) the difficulties and inconvenience in installing soldered lighting fixtures.

Lighting fixtures are in reality "fixtures" largely because they are not easily removable and installable. In fact, we have in the term, "removable fixtures," an anomoly which further emphasizes the desirability of standardizing a better term. Why is it necessary to apply certain descriptive adjectives such as *removable lighting* fixtures in describing a device for lighting? Why should not the Committee on Nomenclature and Standards give us a term which directly describes the lighting device known as a fixture? There would be an advantage in a single word and several coined words suggest themselves.

But to return to the subject under discussion, let us consider the great development in the use of the portable lamp in the home. Notwithstanding the paucity of baseboard outlets, modest homes contain many of these lamps and it is obvious that this type of portable lighting furniture has outstripped the ceiling and wall units in popularity largely because they are easily detachable. If the householder is to become interested in lighting he must be able to own his lighting units whether he rents or owns his place of residence. If the units are readily removable the housewife is encouraged to inject her own taste and individuality into them and antiquated and otherwise unsatisfactory units no longer appear to be "fixtures" or to present insurmountable obstacles.

It has been adequately proved[1] that the demonstration of lighting effects is a much superior method of convincing the consumer of the potentiality of lighting than mere verbal description. The

* A paper presented before a meeting of the New York Section of the Illuminating Engineering Society, January 13, 1921.

[1] M. Luckiesh, Electrical Merchandising, Oct., 1919, p. 183; Bulletin, N. E. L. A., Oct., p. 759.

detachable device makes it possible for the fixture dealer to demonstrate the lighting effect of a unit in a room or alcove reserved for the purpose. Furthermore, it greatly diminishes the cost and inconvenience of installing lighting units in the residence for the approval of the prospective purchaser.

The importance of emphasizing lighting effects cannot be overestimated. The fixture dealer who displays and sells merely fixtures is inhibiting the development of lighting. It is a common experience in visiting fixture stores to encounter the display and sale of *fixtures*. Why not cease selling mere objects made of metal, glass, and textiles? Why not sell the lighting effect of these objects? Will not a consumer pay more readily for an object *plus* lighting effect than for an object alone? The aim of lighting units is not to be merely decorative. The final aim is to produce lighting effects. However, the decorative feature of the so-called lighting fixture is commonly emphasized and the lighting effect is relegated to the background and rarely demonstrated effectively.

Light is the most expressive medium[2] we have for producing various moods. The decorator does much with immobile reflected light. His result is one of light, shade, and color. The lighting artist possesses primary light which has greater possibilities than reflected light and the overwhelming advantage of a mobile medium. By the pressure of a switch he can redistribute and tint the light to produce another mood in a room. To do this the decorator must sentence the householder to days of disorder and to considerable expense.

In light we have a powerful ally in subduing monotony. With adequate wiring, with a sufficient number of portable lamps, with properly designed lighting units, with adequate controls, it is possible to utilize the mobility of light. Portable lamps also extend this feature of mobility because besides mobile light we have mobile lighting units. The detachable lighting unit has a great part to play in this program, but if it is to be utilized fully, indifference toward the potentiality of lighting must be overcome. The manufacturer, dealer, contractor, architect, and consumer must appreciate the possibilities. Lighting units with lighting aims must be designed, demonstrated, and installed. Finally, ade-

M. Luckiesh, Lighting The Home, 1920.

quate wiring must be made available in the home and elsewhere. In this brief discussion details must be omitted, but in the references given will be found wiring diagrams for adequately lighting the middle-class residence. The number of outlets must be increased ten-fold over past practice if the potentiality of lighting is to be fully enjoyed by the householder. A hundred outlets in the middle-class house can be justified.

In this campaign for adequate wiring the prevalent attitude toward lighting must be altered. Now the householder thinks of lighting with the same attitude as he views the fuel bill. The cost of adequately lighting a middle-class home is insignificantly small compared with its importance and its effectiveness in making a house a home. It is a matter of five to fifteen cents per day. It is less than the cost of cream for breakfast. It is less than the interest on the investment in bric-a-brac and pictures in the average living-room. The householder spends many times more in beautifying the rooms with draperies, etc., than for lighting. Lighting contributes much more in making a house a "thing of joy" for each dollar expended than any other esthetic element. It is a powerful, inexpensive ally which is not generally understood and therefore not appreciated as it should be.

Residence lighting is the laggard and the reasons for its lack of development are to be traced to lack of appreciation of its possibilities on the part of those who are in a position to develop it. The "removable fixture" is a potential factor; in fact, it may be utilized to a greater extent than any other single factor in bringing the possibilities of lighting to the householder. The electrical industry has had several sad experiences with the lack of foresight in standardization. It is the hope that no error of this sort will be made now. The detachable device is urgently desired. It should be the best than can be designed and then it should be universally adopted. The dawn of a new era in residence lighting is at hand and a standardized, universally adopted, detachable device for lighting units will contribute much to the golden promise.

DISCUSSION.

The papers by Messrs. Caldwell, Luckiesh, McCoy and Shore were discussed together.

THE "REMOVABLE FIXTURE:" THE FIXTURE MAN'S VIEWPOINT.*

BY W. R. M'COY.

The value of the joint meetings of the Illuminating Engineering Society and the Lighting Fixture Manufacturers' Association is indeed great and fully appreciated by the fixture manufacturers. The result of our last joint meeting has been far-reaching and of such benefit to our industry that our council, at a recent meeting, placed its stamp of approval thereon by resolution and made me its official representative to present its views. The resolution is worded as follows:

Resolution.

WHEREAS, The Illuminating Engineering Society has arranged a joint meeting with the New York Division of the National Council of Lighting Fixture Manufacturers, at which meeting the subject under discussion will be the consideration of the merits of a new universal receptacle and method of plugging in fixtures, and

WHEREAS, The Executive Committee of the National Council has had this device presented to them and have been favorably impressed by its merits, and

WHEREAS, The New York Division has had the same device presented to them and has admired its possibilities.

Therefore, be it Resolved, That we accept with thanks the invitation to meet the Illuminating Engineering Society at a joint meeting and request Mr. McCoy, of the Cassidy Company, Incorporated, to represent the views of the New York Division at this meeting.

As suggested in the second paragraph of this resolution the National Council has given this matter careful consideration and has gone on record as being heartily in favor of some such device. Therefore, the question of our viewpoint is easily answered by these acts of our official bodies. Therefore, I shall be exceedingly brief.

* A paper presented before a meeting of the New York Section of the Illuminating Engineering Society, January 13, 1921.

Mr. Herman Plaut, president of the New York Council of the Lighting Fixture Manufacturers' Association, and one of the managers of the New York Section of the Illuminating Engineering Society, sounded the keynote of this paper when he wrote me as follows:

> "What the lighting fixture manufacturers maintain is that if an outlet box is adopted it should be a universal one and it should be commonly accepted by all manufacturers."

The greatest danger of the use of a device of this sort is that if there be two or more types on the market the manufacturer is worse off than before. One of the past sources of inconvenience which in many cases is measurable in money loss is the incorrect information as to whether the fixtures are to be supplied with insulating joints or crowfeet. When the fitter would go to the contractor to erect the fixtures he would often find that he had the wrong material; he was delayed in his work, the owner became peevish and a mole hill became a mountain. Fortunately, this lack of uniformity is being solved. To illustrate, again, the existence of many different types of plugs is a great source of inconvenience. One of the large department stores of New York City has in its employ an expert fitter whose sole occupation is to follow up portable lamp sales and see that the plug on the lamp fits the wall receptacles. While this illustration is outside of the manufacturing field it well illustrates the burden entailed by the lack of uniformity in plugs.

The greatest source of expense and annoyance in our line of endeavor is the lack of standardization.

The National Council of the Lighting Fixture Manufacturers' Association is doing everything in its power to establish a standard in fitters' screws, holders, glassware, etc.; but this would only complicate our problems unless a way be found to standardize the outlets.

If there are several forms of boxes on the market endless confusion will result. The fixture manufacturer is absolutely convinced as to practicability of the idea, providing a way is found to limit the idea to an outlet that can become universal in its use. The message I bring you from the manufacturer is this: There must be only one type and that type must be the best that money and brains can produce.

It may be well to state a few of the reasons why we find this type of a box of advantage. First, we believe that it will have the effect of bringing about better workmanship on the part of electricians. There is a deplorable tendency to-day to leave the outlets in such condition that it is almost impossible to hang a fixture without extension pieces, wood blocks and other clumsy devices which do not give the clients satisfactory results to say nothing of the expense entailed. That a finished box is installed with much more care is shown by the fact that switch boxes and plates installed by contractors are seldom or never improperly installed for the reason that when the electrician leaves them there are no more mechanics to take up the work where he left off and cover up his lack of good workmanship. Moreover, it will eliminate the necessity for the services of an expert mechanic in proving up every wiring contract before fixtures can be installed. The time, expense, and detail involved by this department of a manufacturer or large dealer are beyond the conception of the layman, and any device that will prevent these annoyances and inconveniences, providing it does not add other complications, will be welcomed.

In closing, allow me to draw your attention to a condition rapidly developing that in my personal opinion will compel the fixture manufacturer to regard this method of fixture suspension as an unmitigated nuisance. Within the last few days the information has come to hand that plans are now being made to manufacture two totally distinct types of boxes for this purpose. If this be true, the third, the fourth type, ad infinitum, will pest us and the dawn of the new era will, I fear, be damp, dank, and cold, instead of beautiful and bright as painted for us in our trade magazines.

Therefore, gentlemen, I beg you to make every effort that lies in your power to prevent this misfortune. Let us all write, print, paint and talk the slogan: "There is progress in one, confusion in many."

DISCUSSION

The papers by Messrs. Caldwell, Luckiesh, M'Coy and Shore were discussed together.

THE "REMOVABLE FIXTURE": HOW IT AFFECTS THE CONTRACTOR-DEALER.*

BY W. J. SHORE.

In the introduction of any new devices primarily designed to save labor there are always many divergent opinions. Very frequently, as has been shown in the past, the very people who benefitted the most from these devices were loudest in their denunciations of the loss and harm that would accrue to them if these inventions became popular and were put into universal service.

There are a number of contractors who have expressed opinions against these new devices and some have favored them. The conclusions arrived at in this talk are my own personal opinions and are not to be regarded as an expression on the subject by the contracting fraternity.

If we assume, for example, in this discussion that within the next few years fixtures will continue to be sold at the same rate as in the past, and that each fixture will be adapted for use with these new outlets and that each fixture outlet installed will be of this type, the following conclusions will seem reasonable.

From the contractor's standpoint, the business of installing and furnishing electric lighting fixtures may be roughly divided into three separate and distinct operations. They may all be performed by one contractor or perhaps two or three.

These are:

1. The installation of the wiring and the preparation of suitable electric outlets.
2. The demonstration and sale of the fixtures themselves.
3. The furnishing of the labor, material and general supervision involved in the actual hanging of the fixtures.

If, as previously mentioned, each outlet and each fixture will be adapted for removable service, the following conclusions seem logical and correct:

1. The contractor, instead of merely installing an outlet box and fixture stud, will put in a device which is comparable to a base receptacle. Therefore on the original wiring

* A paper presented before a meeting of the New York Section of the Illuminating Engineering Society, January 13, 1921.

job there will be a decided and definite increase in the amount of labor and material furnished with the result of an increased profit

2. The selling price of fixtures will remain practically the same.
3. The labor, material and supervision involved in the hanging of the fixtures would be done away with absolutely.

It would therefore seem from the above that the additional profit made through the installation of these new outlets would be cancelled entirely by the loss of the profit earned through the labor involved in hanging these fixtures.

Under these circumstances the net result as far as the contractor's business is concerned would apparently be nil; that is to say, he would make no additional profit, but at the same time he would not suffer any loss.

However, there is another angle to this particular phase of the matter. The installation of the new outlets at the time of wiring the job is a simple affair requiring very little supervision and can be handled readily and easily by the workmen on the job. On the other hand, the hanging of fixtures, usually done after all the painting and decoration work has been completed, involves the use of skilled and careful labor, calls for neatness of workmanship and requires special fittings.

The profit on the installation of these new outlets seems to me to afford an easier way of earning money than would the profit earned in hanging fixtures. I think a great many contractors will agree with me in this contention.

However, what I have just said, and the conclusions I have arrived at, are based on the assumption that the rate at which fixtures are now being sold will not increase.

It is my opinion that the use of the proposed type of outlet will stimulate the demand for fixtures to an enormous degree. As a result of the introduction of this new device I believe that not only will more fixtures be sold than ever before, but the contractor dealer will sell a greater proportion of these fixtures than he has in the past.

A few instances would serve to illustrate this point of view. The public is continually subjected to a process of education. In former days when young people married they purchased their furniture with an eye to service and durability, and it was not

considered good furniture unless it would last at least 25 years. To-day, furniture is bought on the basis of style, and the public has been educated to the point where the furniture is replaced from time to time corresponding to changes in styles and decorations.

House furnishings and decorations have followed the same course, but lighting fixtures have not yet reached this stage. The main reason for this condition, it appears to me, is attributable to their method of installation. They constitute a portion of the building and hence are not the property of the tenant, and as a result they do not interest him.

The building contractor and the people who build new homes and apartments will be quick to realize the advantage to themselves of the new outlets. It means the saving of money to them. At an additional cost of the wiring they will put these new outlets in their new buildings, and will then say to the prospective tenants, "We have installed these new outlets for your fixtures, which you can buy to match your scheme of interior decoration, and when you move you can take them with you. They belong to you."

It means that instead of the landlord or builder buying his fixtures by the dozens through keen competition direct from the manufacturer, the tenant or new owner will buy his fixtures from the nearest and most active contractor-dealer.

It means that more of this business than ever before will flow through the contractor-dealer to the ultimate consumer, which in fact represents the proper method of distribution.

The contractor-dealer will have more opportunity than ever before to serve the public. He will be able to demonstrate new types of lighting equipment with greater ease, and less expense to himself and less annoyance to the consumer. In short, the use of these new devices will permit the contractor-dealer to render more and better service to the public.

There are, however, several important objections in connection with the use of these outlets.

1. There should be only one type. It must be a universal outlet. It must permit a fixture made in Brooklyn to be installed in Milwaukee in an outlet made in Bridgeport. The benefits derived will be a maximum under these conditions.

It is needless to state that without this standardization the proposition would not be worth while.

2. With the installation of these new devices which permit anyone to install fixtures, comes the attendant evil of overloaded circuits. Inspections are seldom asked for and it is but natural that the safe carrying capacity of circuits will be exceeded. This objection may be overcome by more rigid rules, better and more frequent inspections or new protective devices; it is not an insuperable obstacle.
3. The great objection claimed by many contractors is that these new outlets will allow janitors, superintendents and other unauthorized persons to install fixtures. As a matter of fact, they do it now, and they do it very poorly indeed. I venture to state that one out of every two gentlemen present has at some time or other installed at least one electric fixture. How many of them soldered the fixtures wires to the outlet wires? In my opinion this objection will disappear of itself when it is realized that a much better connection is made, both electrically and mechanically, than the mess of wires and tape under a fixture canopy.

It is axiomatic that the removal of any obstruction tending to retard or impede the distribution of economic goods will cause a tremendous increase in the consumption and use of such goods.

The lighting fixture of to-day is a permanent fixture, but the lighting fixture of to-morrow will be a "removable fixture." The introduction and application of this idea will stimulate greater demand for fixtures. It will stimulate demand for a greater number of outlets and, in my opinion, in the long run it cannot fail to benefit not only the contractor but the ultimate consumer.

DISCUSSION.

The papers by Messrs. Caldwell, Luckiesh, McCoy and Shore were discussed together.

BEN TOUSLEY: I have been invited by your committee to demonstrate one of the devices to which the speakers of the evening have referred. This device was invented by E. Cantelo White, of the Electric Outlet Company, Inc., and will be known as the "elexit." In designing this outlet, it was necessary to adhere as

closely as possible to the present standard condition now existing in the electrical industry, and to provide a receptacle which would accomplish the double purpose of accommodating the parallel blades of a standard plug and likewise take the prongs of a fixture-hanging plug. In the new receptacle these desirable features have been combined, and as a matter of fact, despite its double utility, the receptacle is considerably smaller than the existing standard receptacle. In frontal appearance the customary round face of the receptacle has been changed to a round triangle design, a copyrighted feature which will make them easily distinguishable in the field. Wall fixtures can be divided into three classes: the "bridge type," "hickey type" and the "center-knob" type. For hanging the bridge fixtures, commonly termed the French sconce type, use is made of a small plug with two parallel blades, curved upward, and with a projection on the top resembling the present stud hook on which such fixtures are now hung. This plug is attached to the wires of the fixtures leaving enough slack to insure the free insertion of the blades into the parallel slots of the receptacle. The plug is simply pushed into the receptacle as a standard plug is at present and the fixture is hung upon the hook—the bridge wedging down tightly between the hook and flush plate, thus insuring it against being accidentally dislodged. The blades are curved upward to secure the mechanical supporting feature, the plug being ingeniously designed to support and connect the fixture through the same element. For particularly flat and narrow brackets, use is made of a very small plug of a similar design, thus making it possible to plug practically every French fixture into the new outlet. To hang the "hickey" and "center-knob" types of fixtures, there have been designed adaptors which can be snapped on the hook of the wall plug and fastened securely by screws. The adaptor for the "hickey" type fixture acts as the hickey, it being tapped to take the rigid stems of fixture of this type. The adaptor for the "center-knob" is attached to the plug in the same manner but is tapped only ¼x27 into which the "center-knob" is screwed. Besides the wall, the ceiling condition must be met. The same type of universal receptacle is used, but the plug is different. It is in halves, each half being attached to one of the fixture wires, and plug is then inserted, the prongs curved in opposite directions to sustain the weight of the fixture

which is hung on the hook which the plug forms when it is in place. With this plug all types of ceiling fixtures can be plugged into the new receptacles. And yet the new outlet, which may be installed in wall, ceiling or baseboard into which can be plugged standard or ornametal lighting fixtures or an appliance equipped with a standard attachment plug, will cost no more than the present flush receptacle outlet made for the standard plug only. In short, the new devices are flush outlets for all lighting fixtures and electrical appliances of the usual capacity employed in residences, apartments, offices, etc. Receptacles for the new outlet will be made by a number of manufacturers under license agreements that provide for absolute standardization. The same is true of the plugs furnished to fixture manufacturers and dealers. The new receptacles and plugs will be interchangeable without regard to the origin of manufacture. Through the patents this reliable standardization will be provided, no matter how many additional manufacturers may be licensed. No device can be called standard unless the interests of persons affected thereby are taken into consideration and their problems properly solved by it. It has been my privilege to present the new outlets in person to the various electrical contractors' groups in New York and to answer their questions. It has also been by privilege to present the device to fixture manufacturers in New York, Philadelphia, Meriden and the other fixture centers and I can say without exception that every fixture manufacturer who has seen the device has endorsed the new method of hanging fixtures. Numerous letters have been received from contractors and other lighting fixture firms whose officials are members of the Board of Managers of the National Council of Lighting Fixture Manufacturers Association, to which organization or to which Board all the various devices of this kind, which have been brought out, have been presented. It is especially gratifying that in these letters it is indicated that the sentiment of the fixture manufacturers is heartily in favor of the device.

H. R. SARGENT: With regard to the subject of the standardization of ceiling and wall plug outlets for fixtures, allow me to say that detachable cap attachment plugs and receptacles for the cap of the same, have been standardized recently, and the attach-

ment plug may now be considered as standard, as being the only device of this kind recognized by reliable manufacturers. A number of manufacturers of attachment plugs got together about six or eight months ago to consider a standardized outlet for fixtures, the last meeting being held about a week ago. At this last meeting, there were present the inventions of seven persons, which, as far as we know, included all of the inventions covering this particular form of device. All of the devices shown had merit and after the merits of each device had been explained to the executives of the different companies represented, a subcommittee of one representative from each company was appointed to decide which invention, or which inventions, should be embodied in a device that would furnish a suitable standard that would be cheap and practical. The next day the manufacturers again assembled and the committee made its report. The eight manufacturers represented feel that standardization is essential and that the device chosen contains the essentials for success as far as design is concerned. The manufacturers who were present represented companies recognized as reliable makers of standard attachment plugs and devices of a kindred nature. I regret that, due to the short notice which I received concerning this meeting, I have no samples to show you. The design of the device which received favorable consideration by the manufacturers is the result of a number of meetings which have been held, at one of which we had the pleasure of receiving the comments of the executive committee of the National Fixture Manufacturers Association; at other meetings various fixture manufacturers and people interested have been kind enough to attend and give us their views. The side wall receptacle is very narrow, the plug is very narrow and very thin, so that it is well adapted to use with the finest fixture, even one of the most delicate design. The ceiling receptacle is interchangeable with the side wall receptacle, and when the plug is inserted in the ceiling receptacle it is absolutely locked so that the fixture cannot be displaced, and the plugs are very easy to attach to the fixtures. We are, of course, very anxious that only one type of device be made as a standard, and this result can be accomplished only through cooperation among the many manufacturers interested in wiring devices. We have the very kindest regard for the previous speaker, and for the company he

represents. We should not care to make any comparison between any of the devices under consideration. I understand that the following eight companies subscribe to the principle of manufacturing a standard device as set forth above: Bryant, Hubbell, Arrow, Hart & Hegeman, Paiste, Benjamin, Cutler-Hammer, and General Electric Company.

Dana Pierce: It is easily understood that the Underwriters, and I include in that term the people who get up the electrical code, have an interest in the subject under discussion very different from that of any other of the groups that have spoken. We do, however, feel the same public interest in the general welfare of all who use electricity. We share the ambition to see electricity more widely used as representing beyond question the safest method of distributing energy whether, for light or motor service, under proper conditions. In making rules for the National Electrical Code, and with the assistance of the other National organizations cooperating with us, and in our Standards of the Underwriters' Laboratories, which we intend to register the advance of the industries and will therefore cooperate with the industries it is our ambition to keep step with the developments of progress, and of convenience as well as of safety. The word safety suggests to me one thought. I am not going to speak dogmatically about it to-night, but it has not been touched upon here to-night and it is perhaps worthy of your consideration. It is the question of safety to persons as affected by electric fixtures. Those of you who have been familiar with the recent development and discussion of electrical rules will appreciate that there has been a great deal of discussion in the past four or five years on the very simple question as to whether an electric fixture should be grounded or insulated. From the point of view of safety, whether of fire safety or safety of persons, the fixture is a better structure to-day than it was formerly. With the simplification of fixtures there has gone hand in hand a greater attention to possible accidents. The tendency of recent years has seen a general trend towards the idea of grounding the fixtures instead of insulating them. The old insulating joint is now gradually in general becoming a by-law, not universal. The National Electric Code to-day permits the installation of fixtures under most any condi-

tions without insulating, and prescribes the grounding of fixtures in the interest of safety. The failures are less than they used to be because of simpler construction, and the tendency is towards grounding rather than insulating those fixtures. The connection with the subject of "removable fixtures" is fairly obvious, I think. The standard fixture outlets which were described should be so designed that they can be installed in such a manner as effectively and reliably to ground the non-current carrying exposed parts of the fixture. An insulated fixture will not find favor with many people it appears, and with most safety and fire protection engineers to-day, and will find less favor with them a year from now. That is an idea which should be considered by the designer of these fittings, by the contractor, the fixture man and everybody else concerned with them. One other point is this: Those of you who are familiar with the National Electrical Code will recognize that there is therein a venerable rule known as the 660-watt rule, which limits a fixture to a maximum of 660 watts. How long that rule will remain in its present condition, whether it should remain or should be changed, and if so how, is a very important question and one on which the introduction of "removable fixtures" and the corresponding change in arrangement of outlets will have a very important bearing. For example with ten outlets on a circuit, and a total of ten single lamp fixtures on, one may be within the 660-watt rule. If, however, those ten fixtures are taken down and the next tenant puts up on each of the outlets a fixture with three lamps, he may exceed the 660-watt limit. The first tenant who used the one lamp outlet was within the rule. The next one who uses two lamps per outlet is also within the rule. The next one with three lamps per outlet, however, will be over-ruled. Those who are not familiar with this problem in all its relations perhaps will not appreciate it at first. As Chairman of the Electrical Committee of the National Fire Protection Association, which brings out the National Electrical Code and as electrical engineer of the Underwriters' Laboratories, allow me to say that I think that the Code Committee and those who from the point of view of the fire insurance companies and the casualty companies are interested in safety are prepared, after proper presentation of the subject to them and after due consideration of all resulting features of electrical inspection, to meet

you to consider changing the rule. We feel that with a proper change in the existing rule, whatever development in the electrical art shall be to the advantage of electrical men and the electrical industry be it manufacturer, contractor, fixture manufacturer, whatever is to the benefit of the American public should be incorporated in the rules and become recognized as good practice. I do not believe that any rule, be it the 660-watt rule or any method of construction, can or should be allowed to stand in the way by reason of a technicality or by precedent. Just how that rule will be approached, just what will be done, just what should be done, we are not yet prepared to say. The evidence is not yet in, and the matter has not even been formally submitted, but I do think that nothing should be anticipated from the Underwriters' which will stand in the way of any reasonable and safe development.

H. S. Wyncoop: I speak as an inspector enforcing the 660-watt rule incidentally against the wiring contractor, and primarily and always against the fixture man, and I am enforcing it against the fixture man because I cannot catch the man who sells the toasters and the grills and the irons and the washing machines. I feel very keenly about this matter because day after day I am obliged not only to make objections which are based upon nothing but theories, but to settle disputes by making assumptions which may or may not be justified. I have seen job after job where the wiring contractors were delayed, although they had done everything that was expected of them, because the architect had persuaded the customer to buy fixtures which placed too many sockets on the circuit. The wiring contractor was held up until some one could adjust the matter, find out whether extra circuits would be run, or whether sockets were to be taken off the fixtures. This condition is all wrong; but we have to enforce the rules until we can get them changed, and I am very glad to see that there is a sentiment growing which at least eventually will result in some change which will put this so-called 660-watt rule into such modified form that it can be enforced favorably and with a sense of satisfaction that one is really calling for something which meets the requirements of safety and is not simply making a man do so and so because something in print says that he must do so.

What we want is for the wiring contractor and the fixture manufacturer to get together and appeal to the Electrical Committee and say: "What do you mean by this rule? Is it aimed at the fixture man only? And does it not apply to any other of the appliances which enter the home? Is the circuit overloaded when there are too many sockets on it, even if use is made of only one socket at a time? Is the circuit overloaded when there is, let us say, a 500-watt iron on it, and also a 500-watt toaster, although the woman of the family cannot be toasting bread when she is using the iron, so that she cannot use them both together?" What is meant by "overloaded?" What is meant by a "normal load" on the circuit? That is what the Code talks about; that is what everybody's code talks about. Isn't the circuit "overloaded" only when the fuse blows? Those are some of the troubles that the inspector makes for the wiring contractor, and the trouble the inspector makes for the fixture man. Someone spoke about the janitor installing fixtures. Who cares whether the janitor installs the fixtures or not? He can install the irons and washing machines, if he wants to. Why not have such an arrangement that even a child can install a fixture, that is, plug it in? Another point that has not been quite clearly brought out is that in our re-survey work we find many cases where fixture splices are not soldered and are only indifferently taped. Tracing this out we find that there are many of such cases which cannot all be due to careless inspectors. Probably at some time after approval the fixtures have been disconnected for heating, or for redecorating of the apartment, or for refinishing.

I am heartily in sympathy with grounding. I think the City of New York was one of the first places where insulating joints were dropped altogether. But how can one ground toasters? How can he ground grills? It is a question, except in bathrooms and other locations, whether the grounding of fixtures is of such a very pressing nature, until some means of grounding these other appliances has been developed. I am not talking against the grounding of a fixture, I only say why should we not ground all these other appliances as well? Simply, I suppose, because it is more difficult.

George Ainsworth: We are fortunate in having with us rep-

resentatives of the Board of Fire Underwriters and Electrical Inspectors. I wish, therefore, to bring up a point which is not connected with the discussion, but which is of vital importance to the wholesale lighting fixture manufacturers, many of whom are present. We are endeavoring to supply the retail market with attractive portable and fixed ornamental lighting units of delicate design along the lines of the popular French boudoir types which are now sold in great quantities by the leading department stores and decorators throughout the country. On account of the underwriters' rulings in regard to the sizes of wires, we find it impossible to make our fixtures look as delicate and attractive, or manufacture them as cheaply, as the foreign manufacturer is able to do. This advantage is obtained by him through the use of small poorly insulated wires which he runs through the arms or which connect his lamp with the receptacle. The small sized wires create a delicate and feminine appearance, which makes such fixtures exceedingly marketable at the present time. A visit to the leading decorating shops and department stores, porcelain and glassware shops in New York City will bear out these points. It seems hardly fair to make the conscientious American fixture manufacturer use a wire that is larger and more expensive than the wires which are permitted in the imported lighting fixtures sold in competition with the American product. The scrupulous American manufacturer is penalized by the narrow or limited application of the rulings of the underwriters. Is it not fair that we ask for immediate relief?

H. S. WYNCOOP: The answer is very easy. An electric fixture with a number 20 or 22 wire which becomes a portable device, is not under the control of the inspection authorities. They will have no more control over the American product than they would have over the French product, and the American manufacturer can thus sell the same kind of stuff that the French manufacturer is selling.

F. A. VAUGHN: I want to call attention to Mr. Luckiesh's first remark that we adopt some appropriate name-word to use in connection with these devices. I have not observed any uniformity in the nomenclature used by the many speakers. This light-

ing-unit hanging device has been called everything from an "inventor's baby" to a "box" and a "plug." Not once have I heard an illumination expert, or illuminating engineer, or a member of the Society mention the expression "lighting unit." It seems to me, at least technically, that this is the logical term to use when referring to what is too often called the "fixture." Reference has also been made to portable "lamps." The Illuminating Engineering Society itself has taken the trouble to define a lamp, yet even Mr. Luckiesh himself calls these "fixtures" that stand upon the floor "portable lamps" because it is customary for the layman to call them that. Just to start a discussion I'll make a suggestion. It seems to me we could use the words "portable lighting units," and classify them as portable floor lighting units, portable table lighting units, portable ceiling lighting units. If one does not like "portable," he can make it "interchangeable," which is probably better from the point of view of psychology, because the customer is given the suggestion at once of changing, or interchanging, which is a good thing for the commercial fixture designers and others. Or suppose we use the word "attachable" or "detachable" as adjectives. It seems to me that such combinations with the further classifications as to varieties of floor, ceiling, table or wall forms could really be used intelligibly, perhaps intelligently.

M. Luckiesh: I think at this time we ought to coin a word to substitute for "fixtures." I do not know what it would be but by way of starting thought along this line, why should we use unwieldly terms such as "portable lighting device" or "lighting unit?" We do not attach the word unit to the word toaster. We call it a toaster because it toasts. Why cannot we have something like "lighter" or "illuminator" or perhaps a much better single word? I suggest that the proper committee give some consideration to this matter.

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THE SAFETY FEATURES OF INDUSTRIAL LIGHTING.*

BY SAMUEL G. HIBBEN.[1]

The passage of the New York State Code relating to the Lighting of Factories and Mercantile Establishments brought us face to face with a new safety factor—illumination. This is one of the least understood, yet most vital subjects that have to do with economic, humane employment and development of labor, and as our knowledge of better lighting increases, our appreciation of its influence on industrial operation increases in proportion.

In discussing industrial lighting fixture equipment, and particularly its maintenance, we have entered upon an argument disclosing much that is vital in the accomplishment of all three of the desiderata of successful industrial operation, *viz.*, production, speed, and safety. And since production depends upon the other two, or since all three are really synonymous, any arguments applying to the maintenance of a grade of illumination satisfactory for *safety,* will apply equally well to the others.

On account of the breadth of this subject, we shall not attempt to describe the various types of lighting fixtures on the market, nor indicate of what a satisfactory lighting installation consists. One may say in general that good or bad lighting depends upon two outstanding factors. Bare incandescent lamps, or unshielded glaring illuminants that not only do not illuminate but cause a contraction of the pupillary opening of the eye and resultant decrease in seeing ability, form one of these factors. More or larger bare lamps only aggravate this trouble and increase the

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[1] Illuminating Engineer, the Westinghouse Lamp Company.

hazard—the solution is found in the proper use of a good reflector, or a shielding fixture.

The second factor is the matter of insufficient light, and this is very largely influenced by lamp renewals, reflector and lamp cleaning, and the colors of surroundings, or whatever would be involved in maintaining the original installation up to its initial efficiency. It is this very important phase of applied illuminating engineering that will be discussed herein.

Insufficient illumination unquestionably reduces visual acuity, decreases the speed of muscular action, confuses the mind, and leads to accidents. A few figures will illustrate this point.

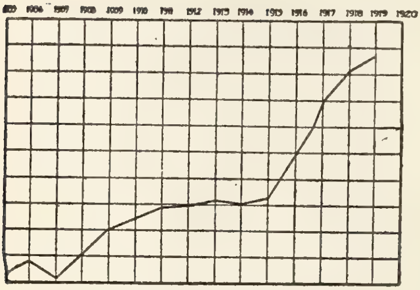
In the coal industry, for example, we think of coal mine accidents as resulting mostly from falling slate or gas explosions, whereas statistics show that for each one thousand men employed underground, there are eleven serious or fatal accidents a year, and for the same number of employees working above ground there are five serious accidents per year. In very few industries is the illumination so wretched, either above or below ground, and this largely explains why we find the abnormally high accident rate in both places. The five accidents that occur uninfluenced by underground hazards can be almost altogether attributed to either poor natural or poor artificial light, and doubtless more than one-third of the underground accidents arise from the same, or a greater insufficiency of light.

As another feature of the close relation between light, speed, and safety, we can cite the example of the tennis ball, which may be perfectly visible to each tennis player when held in the hand just before serving, but which when in rapid motion in the air is almost invisible if the daylight be weak. Any rapidly moving object must register its image upon the brain before we *"see"* it, and as in the photography of objects, there must in human vision be sufficient illumination of that object before our eyes—our human motion picture cameras—will record a clear impression of it. Muscular action cannot begin until after our brains have "developed the film," and hence our speeding up of action, either to produce or to protect, must first start with an understanding of the "time-element" of vision, and an endeavor to reduce this time to a minimum, by higher lighting intensities.

Granting, for a moment, that good illumination is largely dependent upon the care of the lighting equipment, let us see what valuation may be put on poor maintenance, in other words, what is the high cost of poor light. Figures that in general agree with insurance statistics (if they err, it is upon the safe side) show that the total annual serious accidents in industrial plants in the United States amount to 25,000 per year. That is the minimum figure. Out of this 25,000 we find 15 per cent. chargeable to poor illumination—either unshielded poorly directed light, or insufficient light. Now, based upon the average amount of employee's compensations paid, the equivalent lost time of each serious or fatal accident traceable to faulty illumination is 850 weeks, or the total annual time lost is over 3,000,000 weeks, roughly equivalent to the working life times of 1,000 men. If these men were earning $25.00 per week, then practically $80,000,000 in wages are lost annually, through improper lighting. If we add to this staggering sum the doctor's bills, medicines and losses of production we arrive at astonishing figures!

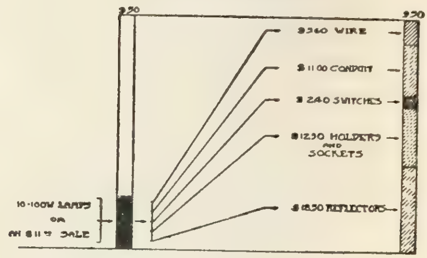
1. One does not often think about the fact that the intensities of artificial light in industrial plants are much below the daylight intensities. We find daylight in factories running from 4 to approximately 50 foot-candles; general artificial lighting in factories for even fine factory work has this year been in the range from 4 to 12; medium factory work between 3 and 9, and sometimes down to ½ or ¼ foot-candle for indoor passageways. Places like stairways, and the positions where accidents are the most prevalent are usually most poorly lighted and if daylight conditions here were reproduced even in the most meager way—even if we only approximated daylight conditions we could reduce accidents materially because statistics show that the largest majority of accidents occur in the night shifts. The percentage is about two to one—two accidents under artificial lighting compared to one accident under daylight conditions.

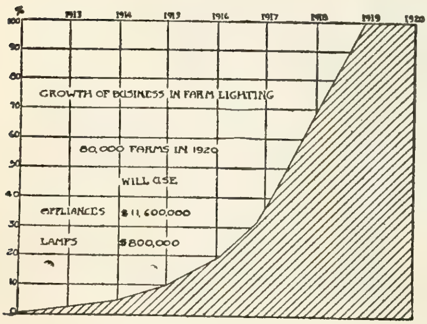
2. How do the manufacturers regard good lighting? Increased production, 79 per cent. of the manufacturers say, is their excuse for good lighting. Decreased spoilage, 71 per cent. say, is their reason. Fifty-nine per cent. of the manufacturers say that fewer accidents constitute their reason for good lighting, etc.



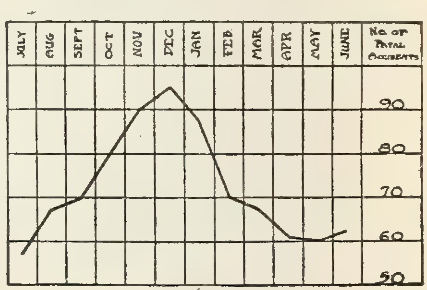
THE GROWTH OF THE LAMP BUSINESS

WHAT GOES WITH LAMP SALES

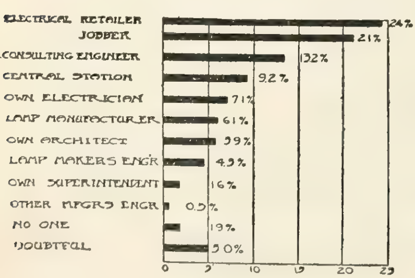




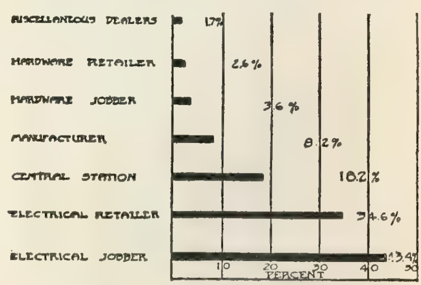
SEASONAL VARIATION OF FATAL ACCIDENTS

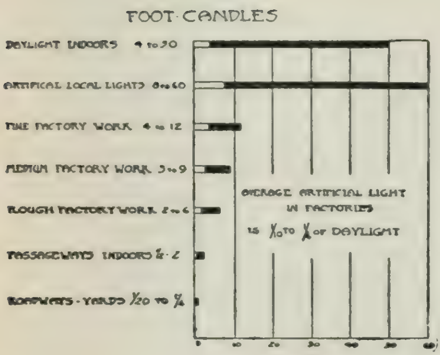


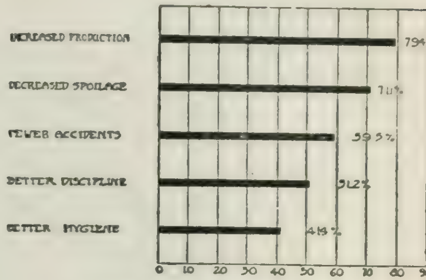
WHERE THE CONSUMER SEEKS LIGHTING ADVICE



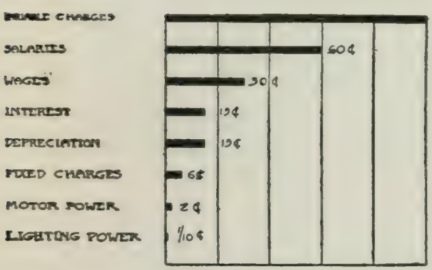
WHERE INDUSTRIAL PLANTS PURCHASE LIGHTING EQUIPMENT



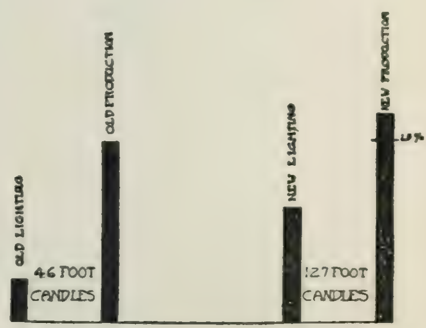




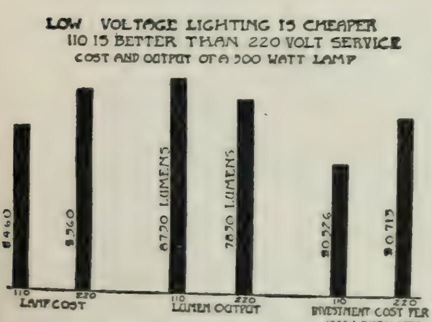
HOW MANUFACTURERS REGARD LIGHTING



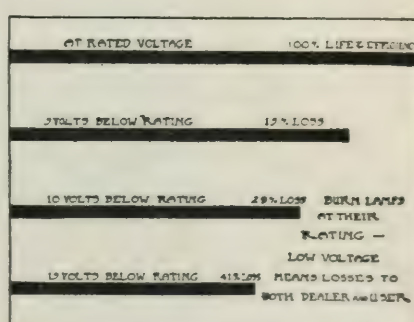
CHARGES PER HOUR AGAINST A MACHINE TOOL



BETTER LIGHTING INCREASES PRODUCTION



INCREASED COST OF 220 OVER 110 · 35%



Offhand the manufacturers admit, without any argument at all, that in half of the cases they would have fewer accidents if they had better illumination.

Now it has been shown that the total cost of accidents, the total disability payments, and the total lost time of industrial operators in the United States amount to more than the total cost of artificial illumination. We should ponder over that fact! The total cost of artificial illumination in the United States is exceeded by the cost of accidents and the loss of production resulting from poor lighting, and yet 59 per cent. of the manufacturers already agree that poor lighting is directly or indirectly responsible for these accidents. Surely, then, it is logical to preach the doctrine of improvement, and the folly of inertia.

3. Data of reputable insurance companies prove that artificial lighting is connected in some way with accidents. In one class of labor during July and August there occur out of a maximum of some ninety-five accidents, about sixty. The rate rises in October, November, and December, falling off in January, February and March, as the days grow longer, and down to a minimum again in May, June, and August, when daylight is a maximum.

This is not new information at all, but it adds weight to the argument that the fatal accidents or the serious accidents prevail in the darker seasons of the year. Other items, such as poor ventilation, low temperatures, etc., undoubtedly enter into these figures, but in tropical latitudes nearly this same ratio is found to exist.

Similarly, the majority of the accidents that do occur in the dark seasons occur when the daylight is insufficient.

4. Now, it can be shown how maintenance is responsible for good light, and conversely what poor light we will get when we do not consider maintenance. The first thing to do to get good illumination and to reduce the danger of the industrial accidents is to look to the interior finish of the rooms or the factories. This is termed "Painting for Light." In other words, ordinary white paint has a reflection value of, say, 82 per cent. Consider the ceiling of a room that is finished in gray-white and with a reflecting value of about 75 per cent., then three-quarters of the light falling on the ceiling surface will be reflected. Now, if we

were to neglect that fact, and were to paint our walls and ceiling medium gray, for instance, which would reflect 46 per cent. of the light, we have cut our available usuable illumination practically in half. In the red and dark colors the reflection coefficients range in value to about 30 per cent. Hence one of the first things that will lead to better illumination and fewer accidents will be the attention given to the interior finishes of the buildings.

This question of light-colored interiors is very pertinent. Not only must one use light-colored paints to obtain high efficiency, but he must clean the paints or must maintain them. Some of us have worked a great deal in the steel mill districts where perhaps the cheapest thing in the factory would be white-wash, and yet this is the rarest thing that one can find. One rarely sees a steel mill white-washed, and yet the illumination of such a plant could frequently have been increased 20 per cent. by a coating of white-wash on black walls. Large expanses of pure white surfaces directly before a workman's eyes are not advisable, as neither are unshaded windows, but a sensible use of both can produce remarkable improvements.

5. Cleaning is essential in maintaining lighting efficiency. When a typical reflector that has been in service several weeks be wiped, its candlepower in a downward direction is increased from 1,000 to approximately 1,350, with corresponding increases in other directions. When the unit is thoroughly washed with soapy water and ammonia, its downward light is increased to about 1,500 candlepower. Obviously a neglected lighting fixture cannot properly perform its work, and the ones that show dirt are in many cases preferable to those that do not, for they will probably be cleaned oftener.

6–7. Though some fixtures in industrial plant lighting are affected more than others, yet all suffer so much that after two or three weeks time the light output is reduced to 85 per cent. of its original amount, or less. With the inverted type of glass bowl, or the semi-indirect types, there is a still more astonishing condition. Merely a thorough washing results in 26 per cent. more usable illumination and the cost of this cleaning as compared to the investment and operating expenses, is very small, scarcely reaching 30 per cent. of the latter. The slogan, "Water is cheaper

than Watts," might well be printed on the card of every efficiency expert.

8. Comparing the depreciation of illumination in the office with that in the factory, we note that the factory units suffer more. This is reasonable because we find more dust and usually an oily dust in the atmosphere of the factory. In a very dirty building, after three weeks of neglect, the illumination may drop from 4.0 to 2.0 foot-candles, and the only reason why such depreciation is allowed to continue is because the reduction is so gradual and the effects are so insidious.

9. If we assume or admit that cleaning of lighting fixtures and of light-reflecting surroundings is essential to efficiency, then why don't we clean? Is the cost prohibitive? It cannot be considered so, in comparison to the results secured. In a typical large building having glass lighting reflectors and rather elaborate commercial fixtures, we find that out of a total annual operating cost of lighting equipment amounting to $14,438, the cleaning and maintenance is represented by $4,633, or about 32 per cent. which may be taken as a fair proportion.

10. Expressed in the terms of an evaluation of the working man and his possible output, the cost of good lighting is perhaps one-tenth to one-quarter of 1 per cent. If we can add to the workman's output, or eliminate lost time represented by not more than two minutes per day, then the value of his output in that short length of time will equal his share of the cost of lighting for the entire day. Expenditures for oil are sometimes greater than for light—are we then evaluating the machine higher than the man?

11. In order to show what could be done with a neglected lighting installation, three factories were taken which had conditions that are found all too frequently. Case 1 was found with 2.6 foot-candles of average illumination intensity. Washing the units increased this illumination 37 per cent. to 3.6 foot-candles. Replacing old lamp bulbs with new lamps of the correct voltage-rating produced another increase of about equal amount, while finally a re-painting of the interior resulted in a final intensity of over 7 foot-candles, all without increasing the power consumption in the slightest. Cases 2 and 3 of this same experiment showed

similar gains that resulted from intelligent maintenance, all adding weight of testimony to the fact that *it pays to clean.*

12. Probably the greatest safety slogan is the old railway crossing sign, "Stop, Look and Listen!" But if the old time employee must stop, wipe his spectacles, and step to a window, in order to look, something is wrong with the illumination. If it is necessary to stop before looking, one has lost something, either efficiency of production or accuracy, or the chance to save one's self from accident and injury. If the factory is well lighted, the employees may look *without* stopping!

All these, and many more arguments, are being discovered as studies are made of efficiency and of safety as influenced by illumination. Many of us will recall the character Scrooge, in Dickens' Christmas Carol who "Liked darkness because it was so cheap," but in these modern times that idea has been utterly replaced by the larger truth that darkness in our industrial operations is very, very expensive.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XVI | JUNE 10, 1921 | NO. 4

CONSTITUTION AND BY-LAWS OF THE ILLUMINATING ENGINEERING SOCIETY

(ADOPTED BY A VOTE OF THE MEMBERSHIP, JANUARY 14, 1907.)

Constitution amended: Jan., 1909; Jan., 1910; Jan., 1911; Jan., 1912; Dec., 1912; May, 1915; June, 1920. By-laws amended by Council: Jan. 28, 1907; Feb. 10, 1910; Mar. 10, 1911; Dec. 8, 1911; Jan. 12, 1912; Jan. 10, 1913; Dec. 14, 1916; Jan. 11, 1917; June 11, 1920.

ARTICLE I.

NAME AND OBJECTS.

Section 1: The name of this association shall be the Illuminating Engineering Society.

Section 2: Its object shall be the advancement of the theory and practice of illuminating engineering and the dissemination of knowledge relating thereto. Among the means to this end shall be meetings for the presentation and discussion of appropriate papers; the publication as may seem expedient of such papers, of discussions and communications; and through committees, the study of subjects relating to the science and art of illumination, and the publication of reports thereon.

ARTICLE II.

MEMBERSHIP.

Section 1: The members of this Society shall be designated as Student Members, Associate Members, Members, Sustaining Members and Honorary Members.

Section 2: A Student Member may be a regularly registered student in an engineering, technical or fine arts course in any college or university acceptable to the Council. A Student Member may have the privilege of participating in meetings and of subscribing to the TRANSACTIONS, at an established cost price, but shall not have the right to hold office, except in a Student Chapter.

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A Student Member shall be eligible to continue in that grade for the fiscal year following his leaving college, and shall be eligible for transfer to the grade of Associate on request at any time within sixteen months after his graduation.

Section 3: An Associate Member may be any one interested in the objects of the Society. At the time of his election he shall not be less than eighteen years of age.

Section 4: A Member shall be not less than twenty-three years of age and shall have been for at least three years engaged in work having a direct bearing on illuminating engineering, or shall have made some valuable contribution to the science or art of illumination.

Section 5: A Sustaining Member may be a company, firm, association or individual interested in the objects of the Society and desirous of contributing to its support. A Sustaining Member, when other than an individual, may be officially represented by an individual. The privileges of Sustaining Members shall be the same as those of other members, except the right to vote and to hold office. All provisions of this Constitution governing the admission, duties and obligations of other members shall, unless otherwise provided, apply to Sustaining Members.

Section 6: Honorary Members may be chosen from among those who are of acknowledged eminence in some branch of art or science related to illuminating engineering. Honorary Members shall be entitled to all the privileges of the Society except the right to vote and to hold office therein.

Section 7: Non-members of the Society may affiliate with a section or chapter of the Society in accordance with the regulations adopted by said section or chapter and approved by the Council. Such affiliates may take part in local meetings, present papers and discussions. They may act on local committees and contribute to assessments for local use. Affiliates will not be privileged to vote or hold executive office.

ARTICLE III.

ADMISSION AND EXPULSION OF MEMBERS.

Section 1: Honorary Members shall be proposed in writing by at least fifteen members, and shall be elected only by the

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unanimous vote of the Council. Voting shall be by letter-ballot. A person elected an Honorary Member shall be promptly notified by letter, and the election shall be cancelled if an acceptance is not received within six months after the mailing of such notice.

Section 2: An application for admission to the Society shall be made in a form prescribed by the Council, and shall bear endorsements or references as to professional or moral standing as follows:

For grade of Student Member—one member of the College Faculty.

For grade of Associate Member—one Member or Associate Member of the Society.

For grade of Member—three Members.

If applicant is not known to the members of the Society, the reference may be made to members of professional societies of good standing or to other persons whose good standing may be readily verified.

(a) *Sec.* 2: A former member whose resignation has been accepted, and who has made written application for re-election to membership, may be re-elected without being required to fill out a new application form.

Section 3: An application for transfer to the grade of Member shall be made in a form prescribed by the Council and bear endorsements or references as prescribed in Section 2.

Section 4: All applications for admission to membership shall be referred to any section Board of Managers within whose territory the applicant may reside, and thereafter passed upon by the Board of Examiners appointed by the Council. All applications for grade of Member shall be approved by the Council or Executive Committee before becoming effective.

(b) *Sec.* 4: All applications for admission to membership in the Society received by any section or chapter, should be sent immediately to the General Secretary, who conducts this work for the General Board of Examiners, as per Article VII, (i) Sec. 8.

(c) *Sec.* 4: Upon receipt of an application, the General Secretary shall determine if it has been properly filled out. If not, he shall return the form and notify the applicant of the deficiency.

(d) *Sec.* 4: If the applicant resides within the territory of a section or chapter, the General Secretary shall notify the Secretary

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of such section or chapter that the application has been received, and shall afford the section or chapter a specified reasonable time to advance objection to the admission of the applicant. The General Board of Examiners shall have entire supervision of inquiry into the eligibility of applicants.

(e) *Sec.* 4: When an application for the grade of Associate Member, or of Student Member, has been approved by the General Board of Examiners, such approval shall be taken as equivalent to an election, and the applicant shall be so notified. Such approvals shall be reported to the Council at its next following meeting.

(f) *Sec.* 4: The General Secretary shall request each person endorsing an application for transfer, or for admission to the grade of Member, and each person referred to by the applicant, to fill out a prescribed confidential form for consideration by the General Board of Examiners. No application for transfer, or for admission, to the grade of Member, shall be acted upon by the General Board of Examiners until replies have been received from the number of persons prescribed by Section 2. In the event of failure to receive replies, or if replies are not sufficiently explicit, the General Secretary may call upon the applicant for the grade of Member to furnish additional names. After serving as the basis of recommendation from the General Board of Examiners to the Council for final action, the application and confidential forms shall be kept in the files of the Council.

(g) *Sec.* 4: Applications for transfer, or for admission, to the grade of Member, when approved by the General Board of Examiners, shall be by them recommended to the Council for final action.

(h) *Sec.* 4: Objection to the admission or transfer of an applicant for any grade of membership must be accompanied by specific reasons for such objection.

(i) *Sec.* 4: Negative votes of three Council members shall exclude a candidate for transfer, or for election, or re-election, to the grade of Member.

Section 5: A member may resign from the Society by a written communication to the Secretary, which resignation shall be accepted by the Council if all his dues and other indebtedness have been paid, and the Society badge has been returned.

Section 6: Upon the written request of ten or more members that, for cause definitely stated in detail, a member of the Society be expelled, the Board of Managers of the section with which the accused is affiliated shall consider the matter, and if there appears to be sufficient cause, shall advise the accused of the charges against him. The accused may then present a written

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defense and appear in person before a meeting of the board. The finding of the board shall then be submitted to the Council of the Society which, within two months, shall finally consider the case, and if a satisfactory defense has not been made, the accused member shall be expelled upon a two-thirds vote of the Council. In the case of one not a member of a section, charges shall be preferred directly to the Council.

ARTICLE IV.

DUES.

Section 1: An entrance fee, payable on admission to the Society, may be fixed by the Council, as may also a transfer fee, payable on transfer from the grade of Associate Member to the grade of Member.

(a) *Sec.* 1: The entrance fee for Members and for Associate Members shall be $2.50, payable on admission to the Society.

(b) *Sec.* 1: A former member whose resignation has been accepted, and who has made application for re-election, need not pay the entrance fee.

Section 2: The annual dues for Associate Members shall be $7.50, which shall include subscription to the TRANSACTIONS of the Society. The annual dues for Members shall be $15, which shall include subscription to the TRANSACTIONS of the Society. The Council may fix an annual due to be charged for Student Members and for affiliates.

(c) *Sec.* 2: The annual dues are payable in advance. Bills for dues shall be sent out by the General Secretary not later than October 10th.

(d) *Sec.* 2: Any member in arrears for dues for a period of four months shall be informed by the General Secretary that he is delinquent and can have no vote or voice in the affairs of the Society nor receive its TRANSACTIONS or other publications until the dues are paid. At the expiration of two months thereafter, if still in arrears, he shall be notified that his name will be presented to the Council as delinquent, if the dues are not paid within one month. If the member continues delinquent, the Council shall drop him from membership at the regular meeting held in June.

(e) *Sec.* 2: From the annual dues paid by each member $5 shall be deducted and applied as a subscription to the TRANSACTIONS for the year covered by such payment. The prices of subscription to the TRANSACTIONS shall be as follows: to Student Members $5

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per year; to non-members residing in the United States, \$7.50 per year; to non-members residing in foreign countries, \$8 per year. Single copies may be sold at \$1 each; provided that volumes reserved shall not be broken to furnish single copies.

(f) *Sec.* 2: The official badge of the Society shall be issued by the General Secretary upon application to any member in good standing, upon payment of \$3.50; provided that Honorary Members shall receive the badge without payment. Each badge shall be numbered and registered in the name of the member receiving it. Members purchasing badges shall be informed by the General Secretary that they are issued with the express condition that if the member resigns or is dropped from the Roll of the Society, he shall return his badge, receiving therefor the sum of \$2.

(g) *Sec.* 2: A certificate of membership in the Society shall be issued by the General Secretary upon application, to any member in good standing, upon payment of \$1.

Section 3: The annual dues for Sustaining Members shall be not more than \$500.

(h) *Sec.* 3: Dues (not exceeding \$500 annually) for Sustaining Members may be elective with the Sustaining Member. TRANSACTIONS shall be sent free of charge to Sustaining Members whose dues are \$25 or more per annum.

Section 4: Honorary Members shall be exempt from all payments.

Section 5: Membership dues in the Society shall date from the quarter of the fiscal year nearest the date of notice of admission to the applicant, provided, however, that the applicant may secure back issues of the TRANSACTIONS (if in stock) by payment of back dues. Applications approved during July, August and September may be made effective October 1st.

(i) *Sec.* 5: The privileges attaching to membership in the Society shall not be accorded to newly-elected members until they shall have complied with the requirements of admission, including payment of entrance fee and current dues. This by-law shall be printed on the form used in notifying a candidate of his election.

(j) *Sec.* 5: If the entrance fee and dues are not paid within one month after the date on which a member has been notified of his election, he shall be finally informed of the delinquency; and if such dues are not paid within two months from the time of notification of election, the Council shall cancel the election, of which cancellation the delinquent and his referees shall be informed. This by-law shall be printed on the final notice above provided for.

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Section 6: A Member or an Associate Member who has been dropped as delinquent may be reinstated by the Council and retain his original date of election upon payment of all back dues, being then entitled to a complete file of the publications of the Society, if in stock, corresponding to the period of delinquency.

(k) *Sec.* 6: A former member who has been dropped for delinquency, may be re-elected to membership without the payment of back dues, in accordance with the practice prescribed for new members in Article III, including the payment of entrance fee. He shall not retain his original date of election.

ARTICLE V.

OFFICERS.

Section 1: The officers of the Society shall be a President, Vice-Presidents equal in number to the number of organized Sections, nine Directors, a Secretary and a Treasurer. Only Members are eligible as officers of the Society.

Section 2: The President, the Secretary and the Treasurer shall hold office for one year; the Vice-Presidents shall hold office for two years and the Directors for three years. Terms of office shall commence the first day of October. A retiring President, Vice-President or Director shall not be eligible for immediate re-election to the same office, and a retiring Vice-President shall not be eligible for immediate election as a Director. At each annual meeting officers shall be elected to succeed those retiring by expiration of term.

Section 3: A vacancy in the office of President shall be filled by the senior Vice-President; a vacancy in the office of Vice-President shall be filled by the senior Director; a vacancy in the office of Director shall be filled by the Council, preferably by selection from members, if any, who at the previous annual election received votes for the office of Director. A vacancy in the office of Secretary or Treasurer shall be filled by the Council. Such succession to office or appointment by the Council shall not render an officer ineligible for immediate election to the same office. Seniority between officers of the same rank and date of election shall be determined by the date of their election as members.

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Section 4: No officer shall receive, directly or indirectly, any salary, compensation or emolument from the Society, either as such officer or in any other capacity, unless authorized by a vote of the majority of the entire Council. No officer shall be interested, directly or indirectly, in any contract relating to the operations conducted by the Society, nor in any contract for furnishing supplies thereto, unless by the unanimous vote of the Council.

ARTICLE VI.

ELECTION OF OFFICERS.

Section 1: Each year not later than April 1st, a Board of Nomination, consisting of the two junior Past-Presidents and of the Past-Vice-Presidents whose terms of office expired in the two preceding Septembers, shall proceed to prepare a nomination ticket containing the names of those whom they deem best suited for the offices to be filled at the ensuing annual election. Nominees for the office of Vice-President shall be so selected that, if such nominees are elected, each locality where there is a section of the Society may be represented on the Council by a Vice-President.

> (a) *Sec.* 1: Each year, not later than March 15th, the General Secretary shall send to the Senior Past-Officer among those designated in Article VI, Section 1, a copy of that section and the names and addresses of the other Past-Officers therein designated. The senior officer shall then forthwith proceed to organize the Board of Nomination and shall submit its report to the General Secretary not later than April 25th.

Section 2: The ticket thus prepared shall be printed and forwarded to members not later than May 5th together with an unmarked inner envelope, and an outer official voting envelope bearing the name and address of the Society and the words, "Official Voting Envelope—Enclosing a Ballot Only." The member voting shall enclose his ballot in the unmarked envelope, which shall, in turn, be enclosed in the outer envelope, which latter shall be endorsed with the name of the sender. Ballots to be counted must reach the General Secretary not later than May 26th.

By-laws are printed in small type.

(b) *Sec. 2*: The General Secretary shall have printed and enclose with the official nomination ticket, Section 2 of Article V, and Sections 1, 2 and 3 of Article VI.

(c) *Sec. 2*: The Roll of members shall designate those who are charter members of the Society. The names of present and past general officers shall be followed by the name of office held, printed in italic type.

Section 3: A member may vote the official ticket above provided for; or he may erase any names thereon and substitute others; or he may substitute a written ballot containing names of his own selection.

Section 4: The President at a Council meeting in May shall appoint, subject to the approval of the Council, five members, not members of the Council, to constitute a Committee of Tellers. This committee shall meet between May 26th and May 30th, and shall receive unopened all ballots from the General Secretary and shall forthwith proceed in secret to count the vote. It shall then prepare in duplicate and sign a report of the results of the vote, one copy of which shall be delivered to the General Secretary and the other forwarded by the Chairman to the Council which shall authorize prompt publication of the results in the TRANSACTIONS of the Society.

(d) *Sec. 4*: The General Secretary upon receipt of the report from the Committee of Tellers, shall at once notify the President-elect of the result of the election. Upon the acceptance of the report of the Committee of Tellers by the Council, the General Secretary shall mail a notification of election to each successful candidate. Such notification shall contain a statement of the duration and duties of office and shall be accompanied by a copy of the Constitution and By-laws.

ARTICLE VII.

MANAGEMENT.

Section 1: The affairs of the Society shall be managed by a Council under this Constitution and under the By-Laws adopted for the execution thereof. The Council shall direct the business of the Society either itself or through its officers and committees.

Section 2: The Council shall consist of the officers of the Society and of the two junior Past-Presidents.

By-laws are printed in small type.

(a) *Sec. 2*: Regular meetings of the Council shall be held once each month, except during July, August and September. Special meetings of the Council or of the Executive Committee may be called by the President. Notice of such special meetings shall be forwarded to the members of the Council or of the Executive Committee at least three days in advance of the meeting. The notice shall contain a synopsis of the business to be brought before the special meeting, and no business other than that so specified shall be transacted at such meeting.

(b) *Sec. 2*: The General Secretary shall, after each meeting of the Council, forward to each member thereof a transcript of the minutes of the meeting.

(c) *Sec. 2*: As soon as feasible after the Council has organized each year, it shall adopt a budget or itemized estimated statement of the year's income and expenses.

(d) *Sec. 2*: For the guidance of the Committee on Papers, the Council shall, as early as possible in the administrative year, determine a maximum limiting sum (to be paid by the next succeeding administration), for the cost of publishing papers and discussions for the annual convention.

Section 3: The Council may delegate any or all of its powers to an Executive Committee of five members, consisting of the President, the Secretary and the Treasurer, ex-officio, and two other members of the Council, which committee shall conduct the affairs of the Council between its meetings.

(e) *Sec. 3*: Should the Executive Committee have taken any action between meetings of the Council, it shall report such action at the first meeting of the Council following; if approved, the action of the Executive Committee shall be as if the action of the Council.

Section 4: The President shall have general supervision of the affairs of the Society under the direction of the Council. He shall preside at the meetings of the Council at which he may be present and shall be ex-officio member of all committees. He shall deliver an address at the annual convention of the Society.

Section 5: Vice-Presidents or Directors, in order of seniority, shall preside at meetings of the Council in the absence of the President.

(f) *Sec. 5*: The President may, with the approval of the Council, assign to Vice-Presidents special activities in connection with particular phases of the Society's work, such as maintenance of contact with sections, chapters, local representatives, etc.

By-laws are printed in small type.

Section 6: The Treasurer shall be the custodian of all moneys. He shall make an annual report, which shall be audited, and such other reports as may be prescribed. The Treasurer and the Secretary, with the advice and consent of the Committee on Finance, shall invest such funds as may be ordered by the Council. They shall pay all bills when audited by the Committee on Finance and approved by the Council.

Section 7: The General Secretary shall be, under the direction of the President and the Council, the executive officer of the Society. He shall prepare the business for the Council and record the proceedings thereof. He shall collect all moneys due to the Society, and deposit the same subject to the order of the Treasurer. He shall personally certify the accuracy of bills or vouchers upon which money is to be paid and shall draw and countersign all checks, which shall be signed by the Treasurer when such drafts are known by him to be proper, duly authorized by the Committee on Finance and in accordance with the necessary vouchers transmitted by the General Secretary with the draft. He shall have charge of the books and accounts of the Society and shall furnish monthly to the Council a statement of receipts and expenditures and monthly balances. He shall present annually a report to the Council for publication in the TRANSACTIONS, and from time to time shall furnish such statements as may be required. He shall conduct the correspondence of the Society and keep full records and perform such other duties as may be assigned to him. The Council may appoint assistants to the General Secretary; one of these may have the title of Assistant Secretary, and shall be under the immediate direction of the General Secretary and aid him in all matters. In the event of prolonged absence or disability of the General Secretary or Treasurer the Council shall authorize one of its members to sign or countersign checks.

(g) *Sec.* 7: The accounts of the General Secretary and the Treasurer shall be audited annually just prior to the annual meeting.

Section 8: The President shall, at the first meeting of the Council after he assumes office, appoint, subject to the approval of the Council, the following standing committees: a Committee

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By-laws are printed in small type.

on Finance, of three members; a Committee on Papers, of at least five members; a Committee on Editing and Publication, of three members. He may also appoint temporary committees from time to time. Two of the three members of the Finance Committee shall be members of the Council, and the other standing committees shall include at least one member of the Council.

(h) *Sec.* 8: The President shall, at the first meeting of Council after he assumes office, appoint, subject to the approval of the Council, a General Board of Examiners, consisting of three members, to investigate the qualifications of all applicants for admission to membership; to elect or reject applications for the grades of Associate Member and Student Member, reporting their action to the Council; and to make recommendations to the Council regarding applications for transfer, or election, to the grade of Member.

(i) *Sec.* 8: The correspondence regarding applications for membership, and in reference to the qualifications of applicants, shall be conducted by the General Secretary for the benefit of the General Board of Examiners.

(j) *Sec.* 8: The President-elect, upon notification of election, may submit informally to the members who will constitute the Council during his administration, proposed committee appointments, and upon receipt of assurance that the appointments will be ratified, may arrange with the General Secretary-elect, the members of the new Council and the members of the new committees, in advance of the new administrative year, to formulate plans with a view to beginning active work promptly upon the retirement of the existing administration.

Section 9: All committees shall be directly responsible to the Council, and shall act under its direction. The Council may at any time, at its own discretion, remove any or all members of a committee, and thereupon the President shall forthwith appoint others as hereinbefore provided; in the failure of the President duly to appoint such a committee, the Council may make the appointment. The terms of the members of all standing and temporary committees shall terminate at the time of the first Council meeting of the new administration of each year. In case of failure to appoint new standing Committees on Finance, on Papers and on Editing and Publication, the retiring committees shall continue to act until their successors are appointed.

By-laws are printed in small type.

(k) *Sec.* 9: The appointment of committees to report upon scientific and engineering subjects shall be authorized only by a majority vote of the Council, which shall be taken by letter-ballot. When such a committee is thus authorized, the President shall appoint the members thereof, subject to approval by vote of a quorum of the Council.

(l) *Sec.* 9: So far as possible, all reports of committees to the Council shall be in writing and signed by all the members of the committee, or an explanation shall be offered by the chairman for the absence of any signature. If only an oral report of committee work can be rendered, the chairman or other member making such report shall state if the subject matter has been submitted to the other members of the committee, and shall offer an explanation if this has not been done. The duties of all committees not specifically defined in the Constitution and By-laws shall be outlined by the Council at the time of appointment or reappointment.

Section 10: The Committee on Finance shall have direct supervision of the financial affairs of the Society, and shall present to the Council an annual report on its financial condition. It shall approve all bills before payment, and shall make recommendations to the Council as to the investment of moneys and upon all specific appropriations. No payments other than routine office expenses shall be made by the General Secretary or Treasurer, except upon the authorization of the Committee on Finance.

Section 11: The Committee on Papers shall have general supervision of all papers to be presented before the Society, and shall have the duty of preparing the programs of general meetings of the Society and procuring papers for presentation before such meetings. No paper, discussion, communication or report shall be printed in the TRANSACTIONS of the Society or elsewhere until approved by the committee.

(m) *Sec.* 11: The Committee on Papers may direct the Committee on Editing and Publication to make such revision as may be considered necessary or desirable, of papers and communications offered for publication; in case of such revision the manuscript shall be returned to the author to obtain his consent thereto, and should such consent by refused, the paper or communication shall not be accepted for presentation before the Society.

(n) *Sec.* 11: The acceptance of a paper or communication for presentation before the Society or any section thereof shall not be considered a guarantee of its publication in the TRANSACTIONS.

By-laws are printed in small type.

Section 12: The Committee on Editing and Publication shall edit all discussions of papers presented before the Society or any section thereof, and shall decide all questions of detail regarding the publication of papers, discussions and communications. The TRANSACTIONS and other publications of the Society shall be in direct charge of this committee.

(o) *Sec.* 12: The Committee on Editing and Publication may, at its discretion, abridge discussions for printing. The committee shall cancel remarks that do not bear directly on the subject under discussion, or that deal in personalities or have manifestly a purely commercial object.

(p) *Sec.* 12: All papers, discussions and other matter intended for publication in the TRANSACTIONS shall, so far as possible, be revised and edited in manuscript and not in proof.

(q) *Sec.* 12: A revised report of any member's discussion on any paper must be received at the general office of the Society within ten days after it has been mailed to the member, otherwise revision shall be made by the Editing Committee.

(r) *Sec.* 12: The TRANSACTIONS of the Society shall be issued nine times per year, at intervals of approximately 40 days, *viz.*: No. 1, Feb. 10th; No. 2, Mar. 20th; No. 3, April 30th; No. 4, June 10th; No. 5, July 20th; No. 6, Aug. 30th; No. 7, Oct. 10th; No. 8, Nov. 20th; No. 9, Dec. 30th.

Section 13: Five members shall constitute a quorum of the Council. The "Vote of the Council" shall be a vote of the majority of the members present and forming a quorum, except where a letter-ballot is prescribed, when the "Vote of the Council" shall be a vote of the majority of the entire membership of the Council.

ARTICLE VIII.

MEETINGS.

Section 1: The annual meeting of the Society shall be held on the second Thursday of October of each year at a place in the State of New York designated by the Council, when a report of the proceedings of the Society for the past fiscal year shall be presented by the Council, which report shall be verified by a majority of the Council, including the President, Treasurer and General Secretary.

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Section 2: An annual convention of the Socieity shall be held on a date and at a place fixed by the Council, for the presentation and discussion of professional papers and subjects. The President shall deliver a presidential address at this meeting.

Section 3: Other meetings of the Society as a body may be held at such time and place as the Council shall direct, at which no business affecting the organization or policy of the Society shall be transacted. Notice of all such meetings shall be sent by mail or otherwise to all members at least ten days in advance of a meeting.

ARTICLE IX.

SECTIONS.

Section 1: Sections of the Society may be authorized in any State or locality where the membership exceeds 50.

> (a) *Sec.* 1: Upon petition for the authorization of a section of the Society, the Council may accord such authorization if the necessary membership exists within the locality specified in the petition.
>
> (b) *Sec.* 1: Meetings of the sections shall be held at times and places fixed by the Boards of Managers, but preferably before the 15th of the month. When suitable papers or lectures are available, meetings may be held preferably monthly except during July, August and September.

Section 2: Each section shall nominate and elect a Chairman, five Managers and a Secretary.

Section 3: The officers of a section shall be elected annually by the members affiliated with the section, the election to be in accordance with a procedure fixed by the Council.

> (c) *Sec.* 3: Procedure in nominating and electing section officers shall be as follows, except when other procedure shall be authorized by the Council:
>
> A section nominating committee shall be appointed by the Section Board of Managers at a meeting held not later than March 1st of each year. The appointment shall be reported to the General Secretary. This committee shall consist of five members of whom at least two shall be past officers of the section or members of the Council.
>
> Not later than March 15th of each year, the General Secretary shall notify the chairman of the committee that it is the committee's duty to prepare a nomination ticket containing the names of those whom they deem best suited for the section offices to be filled at

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the ensuing annual election. The report of the committee shall be prepared in duplicate, one copy shall be submitted to the Chairman of the section and the other copy shall be delivered to the General Secretary not later than April 25th. The ticket thus prepared by the Committee on Nomination shall be printed and forwarded to all section members not later than May 5th, in connection with the ballots for election of general officers. The election of section officers in other respects shall be carried out in a manner similar to that prescribed for the election of general officers, save that a copy of the report of the Committee of Tellers on the results of the section election shall be mailed as soon as prepared, to the Chairman of the Section and to the Chairman-elect. A vacancy in the office of Chairman, Secretary or Manager shall be filled by the Section Board of Managers.

Section 4: The business of a section shall be conducted by a Board of Managers, which shall consist of the Vice-President of the Society representing the locality of the section, and the Chairman, Managers and Secretary of the section.

Section 5: The Section Board of Managers shall annually, at the first meeting of the Society year, appoint a Board of Examiners to pass upon applications for membership.

(d) *Sec.* 5: The Board of Examiners of a section shall consist of the Chairman, the Secretary and one Manager of the section.

Section 6: A section may formulate by-laws for its conduct, which shall conform with the Constitution and By-laws of the Society and with the policy of the Society as fixed by the Council. Upon approval by the Council, proposed By-laws may be adopted by a two-thirds vote at a regular or special meeting of the section; notification of such meeting, together with a copy of the proposed by-laws shall be sent to all members of the section at least ten days prior to the date fixed for its holding.

Section 7: Any proposed action of a section not relating to the holding of meetings and the discussion of papers shall be submitted to the Council of the Society for approval prior to being put into execution.

Section 8: The expenses of sections incurred for postal card notices of meetings shall be paid from the general fund of the Society. In cases where there is no desirable auditorium available free of charge, the Council shall authorize the rental of a

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hall, the expense to be payable from the general fund of the Society. Other expenses than these to be payable from the general fund of the Society must first be authorized by the Council of the Society.

(e) *Sec.* 8: As early as possible in the fiscal year the Secretary of each section shall submit to the Committee on Finance a budget of section expenses for the year.

(f) *Sec.* 8: The Treasurer may deposit with the Secretaries of sections a sum of money, the amount to be fixed by the Council, to provide for current expenses.

(g) *Sec.* 8: The General Secretary of the Society shall supply to each section all stationery and printing, aside from postal card notices, necessary for the conduct of its business.

Section 9: A Section Board of Managers may authorize, and shall provide for the payment by local assessment of, any expenses of a section beyond those authorized to be paid from the general fund of the Society.

Section 10: Papers shall be approved by the Section Board of Managers prior to presentation before a section. Manuscript of papers approved should be forwarded to the Committee on Papers sufficiently in advance of date of presentation to enable advance copies, if a paper be approved by that committee for general presentation, to be printed and sent to all sections for distribution prior to presentation before the sections.

Section 11: Reports of discussions shall be forwarded promptly to the General Secretary who shall mail them at once to members for revision.

(h) *Sec.* 11: The Secretary of each section shall forward to the General Secretary not later than five days after a meeting of a section, a statement of the attendance and of the business transacted, for publication in the TRANSACTIONS.

(i) *Sec.* 11: The Secretaries of sections shall send monthly to the General Secretary, not later than five days after a meeting of ceding month.

Section 12: Should the membership of a section fall below 50, or the average attendance at meetings not warrant the expense of maintaining the organization, the Council may cancel its authorization.

By-laws are printed in small type.

Section 13: Sections shall abide by the Constitution and By-laws of the Society and conform to the regulations of the Council. The conduct of sections shall always be in conformity with the general policy of the Society as fixed by the Council.

ARTICLE X.

LOCAL REPRESENTATIVES AND LOCAL CHAPTERS.

Section 1: When authorized by the Council, the President shall appoint, subject to the approval of the Council, local representatives, or local representative committees, resident in cities or localities where it may be deemed desirable to provide representation with a view to promoting the work of the Society.

(a) *Sec.* 1: Local representatives shall communicate to the General Secretary information concerning local developments in which the Society may be concerned; shall endeavor to promote occasional meetings under the joint auspices of the Illuminating Engineering Society and local organizations with a view to fostering interest in the work of the Society; and shall in any other manner which may commend itself seek to develop local knowledge concerning the objects of the Society and to advise the General Secretary when opportunities arise for the Society to promote its objects.

(b) *Sec.* 1: Local representatives may obtain Society stationery upon application to the General Office. Local representatives' expenses for the correspondence may be billed to the Society.

Section 2: Upon petition of ten or more members of the Society, resident in any city or locality, or associated with any college as teachers or students, the Council may authorize the formation of a chapter to meet, receive papers and discussions. Such chapter may elect necessary officers and shall report all business and other activities promptly to Council.

A chapter may raise funds for operation by assessment among its members, and non-member affiliates, but may not incur any obligation against the general funds of the Society or otherwise in the Society's name, without the specific authorization of the Council.

By-laws in harmony with this Constitution and acceptable to the Council, may be adopted by a chapter, and unless so authorized any proposed action of a chapter, not relating to the holding of

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meetings and discussion of papers, shall be submitted to the Council for approval prior to being put into execution.

(c) *Sec. 2*: Upon petition for the authorization of a local chapter of the Society, the Council may accord such authorization if the necessary membership exists within the city or locality specified in the petition.

(d) *Sec. 2*: The member of the local chapter appointed to act as Secretary, shall, not later than five days after a meeting of the chapter, send to the General Secretary a statement of the attendance and of the business transacted, for publication in the TRANSACTIONS.

(e) *Sec. 2*: The duties of local representatives, as outlined in By-law (a) Sec. 1, shall devolve upon the managements of the local chapters.

ARTICLE XI.

GENERAL.

Section 1: The fiscal year of the Society shall be October 1st to September 30th.

Section 2: A quorum of the Society shall consist in number of one-tenth of the total number of members as listed in the Society's records at the close of the last fiscal year.

ARTICLE XII.

AMENDMENTS AND BY-LAWS.

Section 1: Proposals to amend this Constitution shall be made in writing to the Council and signed by at least 100 members and shall reach the general Secretary not later than April 1st. The Council shall consider such proposals and direct the General Secretary to send out a letter-ballot on their adoption. Votes to be considered shall be received not later than May 26th, and shall be referred unopened to the Committee of Tellers who shall count such votes and make a sealed report, which shall be presented to the Council and announced by a publication in the TRANSACTIONS of the Society. An affirmative vote of two-thirds of the entire vote cast by qualified members of the Society shall be necessary to secure the adoption of an amendment. Unless otherwise provided in the proposal, an amendment shall take effect October 1st following its adoption.

By-laws are printed in small type.

Section 2: By-laws in interpretation of the spirit and letter of this Constitution and for its execution may be adopted by a majority vote of the entire Council. Votes on By-laws shall be by letter-ballot. Each by-law proposed or adopted shall state the article and section of article of the Constitution to which it relates.

(a) *Sec. 2*: A proposed by-law shall not be submitted for letter-ballot until approved at a meeting of the Council or Executive Committe. The letter-ballot shall be conducted by the General Secretary, who shall send a copy of the proposed by-law to each member of the Council at least ten days before the Council meeting at which the result of the letter-ballot will be reported. A proposed by-law shall become effective upon the receipt by the Council of a report showing a concurring vote of a majority of the entire Council.

By-laws are printed in small type.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XVI JULY 20, 1921 No. 5

INTERIOR LIGHTING OF BUSSES*

BY L. C. PORTER AND R. W. JORDAN

Several years ago, the increasing cost of labor and materials so affected the street railway companies that they became unable to extend their lines and still show a dividend at the end of the year. In time, the operating costs increased to such an extent that some companies were put to considerable embarrassment to continue the operation of existing lines. This was especially true in some of the smaller cities, and it became necessary, eventually, for the street railroads to raise their fares from five cents to six cents, and even more. Of course, a hue and cry was immediately raised by the public, who realizing that their pocketbooks were touched, and not understanding why such increases in fare were necessary, considered it a case of a large monopoly trying to gouge them. It was this peculiar twist of the public mind in refusing to believe that a fare of more than a nickel was just that gave rise to the "jitney bus."

The omnibus was peculiarly adapted to entering the transportation field at the time when public opinion was against the street railway companies. The cost of transforming an old truck, or automobile, into a passenger carrying vehicle, was extremely low; in fact, it could be done by the average man, with the use of a little ingenuity, and some old parts obtained from an auto junk dealer.

Moreover, the 'bus had some advantages, which no street car could outdo. The most important of these, and the one which has made the bus what it is to-day, is its extreme flexibility. It is an independent vehicle, requires no rails or poles, and will run on any road.

* A paper read before the New York section of the Illuminating Engineering Society, March 10, 1921.

An unusual blockade, such as a fire, does not tie up the service, but simply causes a detour. This flexibility, together with the advantage of being able to change from an unprofitable to a profitable route at will, has been the foundation of the numerous bus lines now in operation.

As long ago as 1898, the Mack Company, now the International Motors Company, built a bus for sightseeing use in Prospect Park, Brooklyn. In the intervening years, many busses were built for sightseeing purposes, and to carry hotel guests to and from railway stations; but with the exception of the Fifth Avenue busses, none appeared which could be classed as "common carriers" until the war period caused an increase in street railway fares.

The first "jitneys" were simply ordinary touring cars fitted up to carry extra passengers, although occasionally a light truck with seats arranged along the sides would make its appearance. These first adventures into the transportation field found the public willing to accept any kind of service, and practically no comforts, if only it were possible to "put something over on the street car company" and pay only a nickel fare.

As a result, the first jitney owners literally coined money, and caused more men to enter the business.

As competition between jitney owners became greater, the service and type of equipment began to improve. The ordinary touring car with a special body, was gradually replaced by a special enclosed body placed on a light truck. The first of these busses was a very crude affair, with little attention paid either to the physical comfort of the passenger, or to the lighting of the vehicle. When packed full, its capacity was about twenty persons,—half of whom were obliged to stand. The seats were arranged along the sides, the driver having a separate seat in the left front of the bus. These busses usually had a maximum of two lamps, and 2-cp. bulbs enclosed in dome fixtures were used. The domes were placed along the center line of the bus, one about three feet from the rear, and the other about five feet from the front. When both lamps were lit, which was seldom the case, the intensity of lighting was not sufficient for a woman to count the change in her pocketbook.

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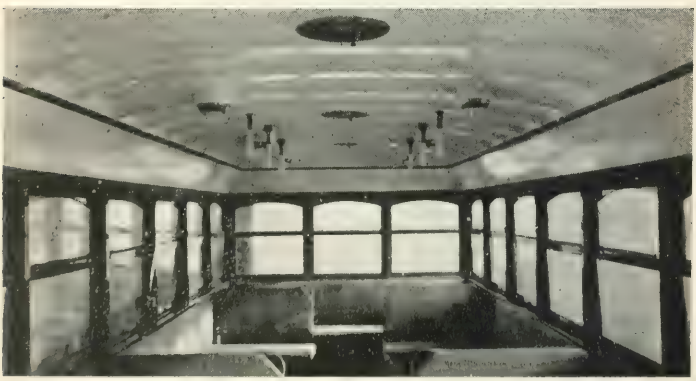
Fig. 1.—Ceiling lighting units.

Fig. 2.—Omnibus for track service.

Fig. 3.—Exterior of a "Jitney bus."



Figs. 4, 5 and 6.—Interior of busses.

The novelty of traveling in busses is gradually wearing off, and the public is beginning to demand a few comforts as well as a cheap ride. The result is, that the tendency for the past year has been to build larger and better busses.

The newer type of bus has seats arranged as in a street car. (See Figs. 5 and 6) It has a seating capacity of about thirty passengers, and can carry forty passengers easily. The seats are comfortable and well upholstered, and the lighting intensity has been increased. These latter busses are in a large part owned by companies engaged in operating bus lines, and not by the independent owners. When busses are operated on a business basis by competent companies, the increase in lighting intensity is marked.

That busses are here to stay must be conceded. Perhaps the independent owner, and the so-called "jitney" bus will disappear, but the number of busses operated by competent companies, and running on regular schedules, will increase.

Efforts were made by the authors to ascertain how many busses are in use to-day but no complete and accurate data seem to be available. Many of the chassis manufactured by the various truck companies are fitted with bus bodies after leaving the factory, and often trucks in other service are converted into busses. However, it is known that there are 600 different bus lines in operation in California, averaging between 5 and 6 busses per line, and observation in any of our large cities shows that the total number of busses in the country must be large and rapidly increasing.

It will not be surprising if the street railway companies commence to use busses as feeders to existing trolley lines, as extentions into new territory and as aids to the trolley car during the rush hours.

Busses are also being built to run on tracks. As shown in Fig. 2 these railway busses are very pretentious affairs. The main use for them is to take the place of steam cars on the short railroads so common in the Southern States. Unfortunately we have no lighting data on these busses, but do know that ten, fifteen candlepower lamps are used in reflector equipment. It would appear that the interior of the bus is fairly well illuminated.

Busses used for traffic such as just mentioned, must have lighting that can be favorably compared with that in a street car; that is, the intensity on the reading plane must be sufficiently high to read newsprint comfortably. To do this, and still keep the load on the generator and storage battery within practical limits, is the problem before us.

In many respects the lighting problem in a bus is comparable to that in a street car. The general seating arrangement and proportions of length to width are similar. The same necessity for good lighting exists; such, for example, as safety and comfort of passengers, advertising value to the operating company, etc. In street car service the public has demanded good ventilation, proper heating, comfortable seats, and good lighting. In many cases these demands have been enforced by public service commissions and it is reasonable to suppose that they will sooner or later extend their authority to busses. It is desirable for the operating companies themselves to take the initiative along these lines, thus securing the approval and good will rather than the animosity of the public.

Some notice of bus lighting has been taken by various legislative bodies, but the requirements are couched in very vague terms as a rule. The state of California, for example, requires a bus to have "an interior light." The city of Paterson, N. J., requires a bus to be "properly lighted" neglecting to specify what definition to give to the term "properly lighted." Elizabeth, N. J., requires busses having a passenger carrying capacity of about 20 to have three interior dome lamps and larger busses to have five. As a rule, through lack of authoritative information, the public service commission have left lighting requirements more or less alone.

There are two fundimental differences in the actual lighting problems as presented by a street car and a bus. In the bus the head room is very low, about six feet in the average bus, and, the source of power, being a storage battery or battery and generator, is limited in bus service. Outside of these differences it is desirable in a bus as well as in a trolley car to have lighting which gives an intensity sufficient for reading, light sources so located and screened as not to cause eye strain to either seated or standing passengers, and intensity and direction of light such as to be free from glare and sharp shadows.

A large amount of study and experiment has been put on street car lighting. In the problem of lighting busses the results of this work can be used to good advantage.

Before attempting to develop a new system of bus lighting the authors decided to make a survey of the various systems of lighting now in use. They visited various cities in the East, including Boston, Hartford, New Haven, Bridgeport, Philadelphia, Washington, Cleveland, Albany, and the towns and cities surrounding New York City and Newark, N. J.

The general practice was found to be to place either two lighting units in the body of the bus, located on the center line of the ceiling, or four units located two on each side of the ceiling. In either case, 2-cp. lamps were found to be in general use, although some busses were found equipped with 4-cp. lamps. The lighting units were shallow domes, fitted with either clear, frosted, or prismatic glass.

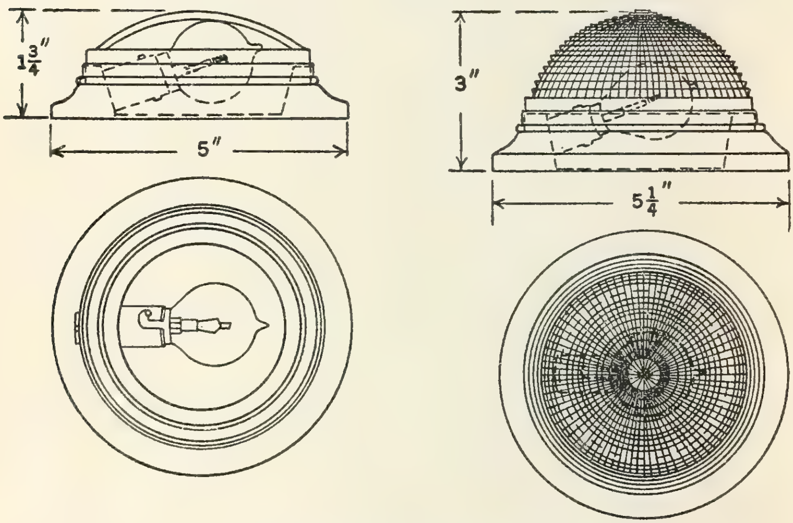
Having found the types of busses in various cities to be very similar, the use was secured of a representative bus, (Fig. 3) and most of the photometric tests were made in that bus at Harrison, N. J. It was felt that more accurate data could be obtained in this way than by taking tests in various cities.

In making the tests use was made of a type of dome which had a base about five inches in diameter, as shown in Fig. 7. Three different types of glass were used in these domes. The domes are large enough to accomodate an S-11 bulb lamp. This size bulb enables the use of as high as 21-cp. filaments which are ample for bus lighting. As may be seen from the diagram, the body of the dome is a metal stamping. The glass in one case is a shallow bowl of either clear or frosted glass, and in the other, a prismatic hemisphere.

Tests were made using various numbers of domes in the bus. The arrangement of the domes was such as to conform to standard practice. The diagrams show the positions of the domes in the ceiling of the bus. In the diagram (Fig. 9) the heavy lines give the outline of the ceiling; the dotted lines show the position of the seats and steps. The lighting units are indicated by the small circles spaced along the center line, and the stations at which photometric readings were taken are shown by cross marks.

Observations were made on the reading plane which in this case was taken as 40 in. from the floor of the bus. The distance from a station to the side of the bus was in each case 1.5 ft. The spacing of the stations, 30 in. apart, was taken for convenience in making the tests, each station being directly opposite the center of a window. All diagrams are drawn to scale. The interior of the bus was dark brown and varnished.

The two dome arrangement shares honors in popularity with the four dome arrangement. Using two lamps of 2-cp. each the load on the battery is less than one ampere for the interior lighting. This fact undoubtedly influenced the early builders to use



Figs. 7 and 8.—Dome lighting unit.

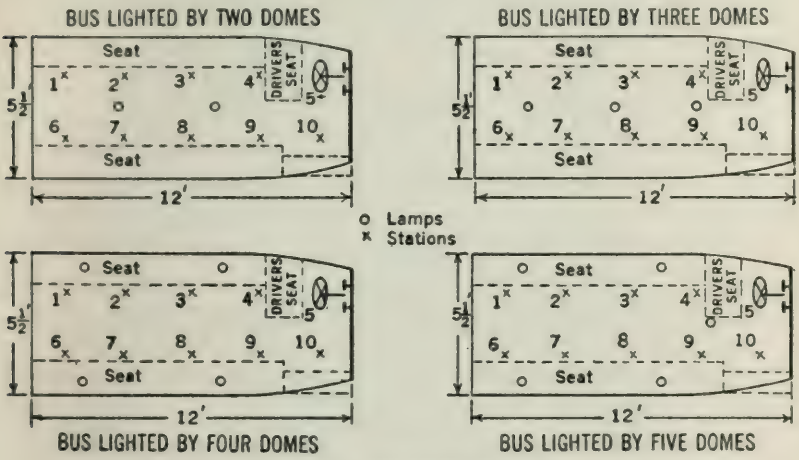
only two domes. As light is a good merchandising agent the four-dome arrangement has become very popular for obvious reasons.

In a number of busses use is made of three domes along the center line. The busses in Elizabeth, N. J., are obliged by law to do this, and, to test out thoroughly the possibilities of this arrangement, we decided to incorporate it in our tests. For the same reason and because of the increased number of units, a test was also made using five units.

The first set of tests were made with the idea of determining the amount of illumination secured from the installations as used at present with lamps of 2-cp. and 4-cp.

With the two lamp installation using clear glass domes, the average intensity on the reading plane with 2-cp. lamps was 0.162 ft.c. With 4-cp. lamps the average intensity was 0.43 ft.c. Using frosted glass domes in this arrangement, the average intensity was reduced to 0.112 and 0.313 ft-c. respectively. When prismatic domes were used the average intensity on the reading plane was 0.41 with 4-cp. lamps.

It may be plainly seen that with two domes and 2-cp. or 4-cp. lamps such as most busses of this type use, the illumination is nowhere near sufficient. The highest intensity recorded being only 0.615 ft-c. with 4-cp. lamps and clear glass.



Figs. 9 to 12.—Lighting test stations.

Three domes were now placed in the ceiling along the center line as shown in Fig. 10. When 2-cp. lamps were used with clear glass domes the resultant average illumination was 0.347 ft-c. With 4-cp. lamps this was increased to 0.654 ft-c. Domes with frosted glass were substituted and the average intensity was cut down to 0.187 ft-c. with 2-cp. lamps and 0.458 ft-c. with 4-cp. lamps. The highest intensity recorded was 0.89 ft-c. at station 8, with 4-cp. lamps and clear glass in the dome. The three-dome installation has the advantage of giving a very even distribution throughout the bus, but with lamps of such low candle power, the intensity of illumination is not sufficient for reading purposes.

Referring to the next diagram Fig. 11, the arrangement of the four-dome installation which was used may be seen. Four domes with 2-cp. lamps gave an average intensity of 0.403 ft-c. with clear glass and 0.223 ft-c. with frosted glass. Replacing the 2-cp. lamps with 4-cp. lamps increased the intensity to 0.803 ft-c. with clear glass in the domes and to 0.513 ft-c. with frosted glass. Prismatic domes of the type previously shown were placed in the bus, and an average intensity of 0.56 resulted when 4-cp. lamps were used.

In this installation several improvements were noted. Chief among these was the improvement in distribution, the intensity of light being very evenly distributed. A second improvement had to do with the placing of the units. They were on the side of the bus which had this advantage. If the bus is crowded with standing passengers, two units on each side will be giving light on magazines or papers which seated passengers may be reading. With a center installation there is danger of the units being nearly totally eclipsed by tall passengers. A further advantage is that less light is lost through the windows with this installation than is the case with a center line arrangement.

One more installation was made. This time five units were placed as shown in Fig. 12. From the preceeding tests we concluded that the addition of one more unit would not raise the average intensity sufficiently high for a good reading light, and hence only one size of lamp was installed. With 4-cp. lamps and clear glass in the domes, an average intensity of 0.917 ft-c. was secured. With the frosted glass this was reduced to 0.632 ft-c.

With this installation the dark spot in the front of the bus which was present in the previous tests, was practically eliminated. Moreover, it was found that 2-cp. or 4-cp. bulbs were not sufficient to secure illumination to comply with the requirements of satisfactory lighting. Reading with the bus in motion would be practically impossible even with clear glass domes, which would introduce the harmful effects of glare. Eliminating glare by using frosted glass would endanger the passengers on entering or leaving the bus. The intensity of light would be so low that the passenger would be subjected to those painful and annoying minor accidents, such as are occasioned by stumbling over another passenger or a parcel placed on the floor, or getting stuck in the eye by hat pins.

Much useful information was obtained from these tests in spite of the disappointment in illumination.

Analyzing the test data some very interesting things were found. For example; the average loss due to the use of frosted instead of clear domes, was 33.7 per cent.

It was found that with prismatic instead of clear glass units located on the center line of the ceiling, there was but little loss of light on the reading plane. However, if the prismatic glass unit were placed on the side their efficiency was but slightly better than that of the frosted units.

It was also found that there was a somewhat different per cent increase in lumens on the reading plane when the wattage was increased a corresponding amount with the lighting units located on the center line, or on the sides.

It was further found that it was more advantageous to have the units placed on the center line of the bus. In other words, in changing from a three-unit installation on the center line to a four-unit installation placed on the sides with the same candle power bulbs used in the two cases, an increase in intensity on the reading plane of only about 20 per cent was secured for an increase in wattage of 33⅓ per cent. Thus from the standpoint of efficiency in conserving power the center installation is more satisfactory, but when so placed as has been mentioned before, the lighting units would be shaded by standing passengers and the light would not be secured on such reading material as seated passengers might have.

Having determined what intensities of light are being secured under present conditions, the question of obtaining satisfactory lighting with the equipment which is now in use, was taken in hand. The variable in this problem is the candle-power of the lamp used.

There are several limiting factors to a choice in candle-power. The first is that the lamp must be a standard, or semi-standard. That is, for the convenience of the bus driver, the lamp must be one either carried in stock by all auto lamp retailers, or be one which may be easily obtained by them.

A second factor is that it is desirable to have as few different types of lamps as possible on a single bus.

The third and most important factor is supply system. The

load on the battery, or battery and generator, is the limiting factor in determining the permissible size and number of lamps which may be used in the interior illumination of the bus.

At this point it would be well to ascertain just what lamps may be used. That is, what is the maximum number of lamps of each candle power which may be installed in a bus?

Take a 12-16 volt battery and generator outfit as the first example. By adjusting the generator it may be so arranged as to generate ten amperes safely. Ten amperes however, is too high a charging current for the average storage battery and hence a resistance must be put in the circuit so connected with the lighting switch that when all the lamps are lighted the resistance is cut out and the generator delivers 10 amp. or less as the case may be. When the lighting switch is opened and the lamp load is off, the resistance should be automatically cut in and the charging current to the storage battery reduced to 3 or 4 amp. By proper adjustment of the generator and resistance the system may be so arranged that with the lamp load either on or off a charging current will be continually flowing to the battery. The above arrangement gives the bus owner enough current to secure proper lighting in his bus. With a 6-8 volt outfit 18 amp. may be secured.

In determining what is the maximum number of standard tungsten filament lamps of each candlepower which one can use for interior lighting. The first assumption is that the bus is equipped with two 15-cp. headlighting lamps, one 2-cp. lamp for tail lighting and one 2-cp. lamp for step lighting. The 15-cp. headlighting lamps draw 2.31 amp. each and the 2-cp. 0.47 amp. each for 6-8 volt design, and 1.09 amp. and 0.36 amperes respectively for 12-16 volt design. In the 6-8 volt case there is a fixed load of 5.56 amp. and for the 12-16 volt systems a load of 2.56 amp.

With 6-8 volt system-fixed load of 5.56 amp.

Candle power	Type	No. of interior lamps	Amps.	Total amp.
12	gas filled	7	10.99	16.55
12	" "	8	12.56	18.12
15	vacuum	5	11.85	17.41
15	"	6 (possible)	13.86	19.42
21	gas filled	4	11.24	16.80

The above table gives the number of lamps which can be recommended as being safe loads for the lighting system. That

higher loads may be carried safely is known. One well known motor car company has built a bus body which was equipped with 6 20-cp. 6-8 volt lamps. This bus has been in commission several months and no trouble has been experienced with the lighting system.

With 12-16 volt system-fixed load 2.56 amp.

Candle-power	Type	No. of interior lamps	Amps.	Total amps
12 (Not recommended as it is a very special lamp)				
15	vacuum	6	6.54	9.10
15	"	7	7.63	10.19
21	gas filled	6	6.96	9.52

From the two preceeding tables it may be seen that the 12-16 volt system adapts itself better to interior lighting than does the 6-8 volt system. The advantage of the gas-filled high-efficiency lamp is also plainly apparent.

In making the following tests we were careful to stay within the limitations of the above tables.

Starting as before with two units, the 12-cp. lamps were used in frosted, clear and prismatic glass. The average lighting intensities were 0.78 ft-c. for frosted, 0.95 ft-c. for clear, and 0.76 ft-c. for prismatic.

The intensity through the body of the bus averaged 1.1 ft-c. with clear glass domes. The actual average being brought down by the dark spot in the front of the bus.

When three units were placed in the bus, spaced as previously shown, the average intensities were raised to 1.16 ft-c. for clear glass, and 0.99 ft-c. for frosted glass.

Four units were then placed in the bus. Using the 12-cp. bulbs the average intensities were raised to 1.44 ft-c. with clear glass, 1.11 ft-c. with frosted glass in the domes, and 0.88 ft-c. with prismatic glass. As yet there had been secured no intensity sufficient to warrant recommendation. One thing, however, showed up very plainly at this stage, and that was the ability of the prismatic glass to direct the light on to the ceiling.

When the units were spaced along the center line, a circle of light surrounded the base of each prismatic unit. With a white enameled ceiling, this characteristic should prove beneficial. As some direct light on the ceiling gives a cheerful appearance and much of this would be added to the light going directly downward. This characterist'c proves detrimental in a varnished bus, which

has seen service when the units are placed on the sides. Therefore, the prismatic glass was omitted from the next test as it was decided that the units must be on the sides of the bus to direct the light where it was wanted.

Knowing that with four 15-cp. lamps the load was nearing the maximum in 6-8 volt range, the four unit arrangement was selected for the next test.

Using clear glass domes and 15-cp. lamps the average intensity was 2.89 ft-c. and with frosted glass it was 2-18 ft-c.

With the clear glass in the units, at last a sufficient amount of illumination was secured to enable a passenger to read with ease..

In that part of the bus occupied by the passengers, the average intensity was 3.4 ft-c. The intensity over the exit was about 0.9 ft-c.—sufficiently strong to prevent stumbling, if care is used. However, to be absolutely safe, a step lamp should be installed, not necessarily over 2-cp.

With frosted glass, the over-all average intensity was about 2.2 ft-c. with an average in that part of the bus occupied by passengers of 2.6 ft-c. This is about the maximum which can be secured with a 6-8 volt battery-generator system as used on the majority of busses at present.

In making the foregoing tests, some features stood out. One was that when 12-cp. lamps were first installed in place of 4-cp. lamps, only a very slight increase in illumination resulted. This was due to the fact that the older type of busses are wired with bell wire of about No. 18 size, which does not have sufficient carrying capacity to allow the use of 12-cp. lamps. The drop was such that the lamps were operating at from 3 to 4 volts. It is, therefore, important—particularly in new busses,—to see that the wiring is of sufficient size to carry the load with little voltage drop.

With the four-unit prismatic glass installation with 12-cp. bulbs, a total of 21.1 lumens fell on the windows and undoubtedly most of this light was lost as far as the interior illumination of the bus was concerned. The units were then spaced along the center line at equal distances from each other so that the units at either end were exactly opposite the places occupied by the units when placed two on each side of the bus. With this installation 31.3

lumens fell on the windows. This proved that when shallow domes were used the side arrangement gave a better general illumination in the bus than when the center arrangement of units was used. Most of all it showed that some means of controlling the light distribution is necessary.

From the dome tests it seems evident that the only practical way to improve the lighting without changing the equipment is to use lamps of higher candle power. In many cases this will necessitate rewiring as the sizes of the wire in common use are insufficient to carry an increased load.

If the bus is to be rewired some advantage can be gained by placing the domes in the center of the bus rather than on the sides as regards efficiency of operation and simplicity of wiring. This is overbalanced by the fact that head room must be considered and that the standing passengers will obstruct the light from the seated passengers who may be reading. From data available on street car lighting it is known that an increase in intensity on the reading plane may be secured by painting the ceiling white. This would apply equally well to bus lighting for not only will the intensity on the reading planes be raised, but also glare would be decreased by reducing the contrast between the lighting unit and its background. It would be advisable to use white enamel paint as it is more easily cleaned than a mat surface. Therefore, for a bus of the type used in these tests the best that can be employed, if domes are to be used, would be four 21-cp. lamps in frosted glass domes, which however will still produce insufficient illumination.

Having determined the most practical improvement that may be made in lighting by using the present equipment, the conclusion was reached that dome lighting was very inefficient. A search was therefore made, for reflectors which would satisfy the requirements of bus lighting, namely, the reflectors must be made sturdy to withstand the shock and jar of rough roads and stiff truck springs, and to resist the shock of a passenger grabbing or knocking against them; they must produce the proper light distribution.

The candle-power distribution curve necessary for scientific lighting naturally depends on the size of the bus. At this point

it may be said that for the average latest type bus, with units on the side, a "60-degree" distribution curve would confine the majority of the light to the interior of the bus and allow very little to escape through the windows. A third point to be taken into consideration is that the reflectors should be shallow to allow for headroom which is limited even in the latest type of bus. The fourth point is that a satisfactory pendant must be secured. This pendant must be sturdy, it must hold the reflector securely locked in place, and must have a short overall length. A lighting unit should fulfill all the foregoing requirements to be satisfactory for bus service.

For purposes of comparison various lighting units were installed in the small bus used in the previous tests. The first unit was a light opal, 6-in. by 3-in. reflector, with a suitable pendant.

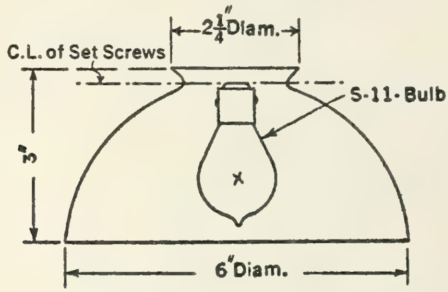


Fig. 13.—Lighting unit equipped with reflector.

The total overall length was slightly under 4 in. The candle-power distribution curve was approximately "60-degree," which makes it very satisfactory for center deck lighting in this case. The glass itself is of rather light weight for bus service.

Three units were installed on the center line of the ceiling in the same positions as previously occupied by the domes. The intensity of light secured with 12-cp. lamps was sufficiently high to justify the assumption that the addition of the reflector equipment would represent a great improvement. The average intensity on the reading plane was found to be 1.81 ft-c. This is a 57 per cent increase over the clear glass domes arranged in a similar manner and equipped with the same 12-cp. lamps. When 15-cp. lamps were placed in the reflectors the average intensity was raised to

3.39 ft-c. This arrangement produces sufficient light throughout the bus for reading purposes, and eliminates the dark spot in the front of the bus without illuminating the windshield to a high intensity. (See Fig. 13).

One of the reflectors was removed and the remaining two units were arranged to conform in spacing with the dome test and 21-cp. lamps were inserted. The average intensity of light on the reading plane with this arrangement was 3.87 ft-c. The light was not evenly distributed but the efficiency of the reflectors as compared to dome units was clearly demonstrated.

Four reflectors were now installed as before, two on a side, with a tilt inward of about 5°. With 12-cp. lamps an average intensity of 2.09 ft-c. was obtained, and with 15-cp. lamps this was increased to 4.37 ft-c. The large increase in light (109 per cent) occuring when 15-cp. lamps were used was undoubtedly due to the change in bulb size from G-8 to S-11 and from a very concentrated filament to one which was comparatively large.

A comparison of the results obtained in the above tests is very interesting. The units having a distribution curve suited to center deck lighting give very satisfactory results when thus placed, but when placed on the side where they do not interfere with the headroom the efficiency is lowered. Thus in increasing the number of units by one third the intensity was increased by one sixth with 12-cp. lamps. However by tilting the reflectors about 5° when in the side positions and using 15-cp. lamps which are more suitable to this reflector there is no loss in efficiency.

In increasing the candle-power in the 3-unit arrangement from 12 to 15 the consumption was increased 47 per cent and the intensity 87 per cent.

By using three 15-cp. lamps in the center as compared to four 12-cp. lamps on the side, the current consumption is 6.9 as compared with 6.3 amp. The center arrangement gives a satisfactory illumination of 3.39 ft-c. average intensity and the other arrangement gives only 2.1 ft-c. which is unsatisfactory, thus indicating the necessity of using properly designed reflectors for this type of lighting. From the standpoint of efficiency the center deck lighting system is desirable from the point of view of power consumption required, number of units necessary, and the simplicity of installation of wiring and maintenance including clean-

ing, etc. The one bad feature is the lack of adequate headroom, but it may be possible to sink the unit partially in the roof of the bus and use the aperture both as a part of the lighting system and as a ventilator.

It is doubtful however if economy in installation expense of the center deck system would offset the disadvantage of the shadows thrown by standing passengers. If busses were built with ceilings comparable in height with those on trolley cars, the center deck system would unquestionably be best.

The next tests were made with a four-unit installation using prismatic reflectors. The reflectors have a 1.5-in. fitter and are satin finish on the inside. These reflectors have been installed in several busses of the latest type. With 15-cp. lamps the average intensity was found to be 3.4 ft-c. and with 21-cp. lamps 4.32 ft-c.

The advantage that may be secured by the use of gas filled lamps is shown slightly in the 6-8 volt service where for an increase of 22 per cent in consumption there was an increase in illumination of 27 per cent. In the 12-16 volt service for an increase of 6 per cent in consumption 27 per cent increase in illumination was secured by the use of gas-filled lamps as compared to the vaccuum type.

These reflectors do not give as satisfactory results as those previously installed. The reasons for this are as follows: First the reflectors are satin finished on the inside thereby reducing the light to some extent; second they have 1.5 in. neck and a satisfactory holder is hard to obtain; third, and most important, the reflectors are so constructed as to be almost of the focusing type and the candle-power distribution is not sufficiently wide. The authors do not wish to condemn prismatic glass and want to say at this point that this particular type of reflector was used in the test solely because certain new busses are so equipped. They have since found a prismatic reflector with 2.25-in. neck which appears to be of much more satisfactory design, but as yet have made no test on this reflector.

A third type of reflector was next installed. This type was a dense opal reflector with a 2.25-in. neck, and the construction is very heavy. With four units in the bus and 15-cp. bulbs an average intensity on the reading plane of 3.76 ft-c. was obtained. This equipment gives a satisfactory reading light, the average

intensity in that part of the bus occupied by seated passengers being 4.3 ft-c.

From the foregoing tests we found out these several important facts. First; contrary to our initial assumption a reflector which approached the focusing type was not satisfactory; second, that with reflectors placed on the ceiling near the sides of the bus with an inward slant of about 5 degrees and a candle-power distribution curve having from 60° to 90° spread, very satisfactory results were obtained.

In reviewing the entire subject the following conclusions are reached. First, that the dome equipment is very inefficient and does not give satisfactory results for the amount of power expended; second, that the reflector equipment gives very satisfactory lighting and should be used. The expense of converting from dome to reflector units is warranted by the improvement in the interior lighting.

Reflector units should be placed on the ceiling near the sides of the bus so that standing passengers will not cast shadows on the reading matter of seated passengers and where they will be in no danger of being hit by the passengers. For the same reason and because of the jar and rough usage to which they are subjected they should be of heavy glass and the pendant should be solid and sturdy.

Of the reflectors tested and those under consideration with the exception of the before mentioned 2-25-in. neck prismatic glass reflector which was not received in time to incorporate in the above tests, the unit recommended for reasons of safety, appearance, and efficiency of distribution, we found most satisfactory is the heavy dense opal. This reflector is of pleasing appearance, sturdy, deep enough to shade the seated passengers from the direct rays of the lamp and is efficient in distributing the light where it is wanted. It is not as efficient as the light opal reflector, but the glass in this latter reflector is less than one eighth of an inch in thickness.

Two pendants were found satisfactory for this class of service; each has a short overall length, is sturdy, and has a pleasing appearance.

The jitney bus lighting field warrants the development of a new reflector especially for this class of service, in which could

be combined all of the best points of the various reflectors now on the market. Due to the limited number of units that can be installed in a bus, it is the authors' belief that reflectors having an asymetric candle-power distribution could be used to advantage particularly for large busses.

The number of units to place in a bus naturally depends upon the size of the bus. In a bus approximately the size of that utilized in the tests, excellent lighting may be obtained by the use of four dense opal reflectors with 21-cp. lamps located on the ceiling, two near each side, the rear ones about 3 ft. from the end of the bus, and the front ones 4 ft. forward of these. The lighting units should be located about 6 in. from the side of the bus and tilted inward about 5 degrees.

While the test showed that 15-cp. lamps gave good lighting, some allowance must be made for depreciation under service conditions, and for that reason it is desirable to use 21-cp. lamps. Use should be made of a pendant of such type as to prevent the possibility of a reflector jarring loose and falling. It is advisable that the ceiling of the bus be white enamelled. For large busses, use should be made of the same system of lighting with six lighting units instead of four.

In conclusion the authors' wish to express their appreciation of assistance rendered in the way of material, data, and test facilities in connection with the above study by the following: International Motor Co., Pierce Arrow Motor Car Co., White Motor Car Co., Packard Motor Car Co., Goodyear Tire Rubber Co., Dayton Mfg. Co., Adam & Westlake Co., Holophane Glass Co., Ivanhoe-Regent Wks. of General Electric, and MacBeth-Evans Glass Co. They are further indebted to Mr. Edgar Parker of the Lighting Service Department of the Edison Lamp Works who assisted in making the illuminometer tests.

DISCUSSION

The papers by Messrs. Porter and Jordan and those of Messrs. Summers and Hulse were discussed together. See page 110.

STREET CAR LIGHTING*

BY J. A. SUMMERS.

Business men have found that light draws trade. This has been so definitely proven that few would attempt to contradict it. We see the results on every side; the crowd gathers where the bright lights are; they stop and examine the brightly lighted show window; they drift unconsciously to the brightly lighted theatre entrance or restaurant. If the street cars are made bright and attractive it is perfectly logical to assume that human nature will react in the same manner with regard to street cars as it does in other lines.

That the public does react in this manner was definitely shown recently in the subway here in New York. On some of the local trains alternate cars had about twenty-five per cent more light than the others and it was observed that the brighter cars were occupied before the others. Experiences of this kind indicate that it is entirely logical to apply merchandising methods to attract passengers.

I have heard some say that it is not necessary to attract passengers. This may be true in some cases, but in the large majority of cases the railway company is exerting every effort to attract the public to its cars.

There is severe competition in many places between the street cars and jitney busses and it behooves the traction company to make their cars as attractive as possible to hold their prestige. The statement that people have to ride anyhow regardless of conditions is not tenable. It is true that a great many are absolutely dependent on the trolleys to get to and from work, but the profits of the company depend largely on the number of people who can be induced to ride who are not forced to ride. Brightly lighted cars are without question a powerful aid in attracting these casual riders, and hence, the proper illumination of cars should receive very serious consideration.

It is unfortunate but nevertheless true, that even at the

* A paper presented before the New York Section of the Illuminating Engineering Society, March 10, 1921.

present time, illumination is often an afterthought or an annoying necessity to be disposed of as expeditiously as possible. Proper illumination cannot be provided by simply ordering several circuits of small lamps to be installed, and thus dispose of the matter without further thought or attention. I am glad to say that most of the large companies realize the importance of illumination and make very thorough investigations of lighting conditions, some of which have been reported in papers before the Illuminating Engineering Society.

There are a great many variables to be considered in planning the lighting of a car. The interior finish of the car, the voltage regulation, arrangements of the seats, and the standard of lighting in the community have a very decided bearing on the selection of the proper lighting equipment.

The interior finish makes a great difference in the resulting illumination. This is true regardless of the reflector equipment. A car with a dark finish is likely to appear dark even though the photometer shows that the illumination is adequate. The psychological effect of such a car is depressing and the passengers feel that there is insufficient illumination,—hence the unjust criticism. A gloomy car also suggests uncleanliness and frequent resentment is expressed by passengers because of being compelled to ride on "dirty, gloomy cars." This feeling does considerable harm to the railway company not only by causing the antagonism of the public but by repelling the short-haul passenger.

A flat white ceiling with light color woodwork is of course most desirable from an illumination standpoint, but a light tinted ceiling, which many companies prefer, is quite satisfactory. Such a finish will add 20 to 40 per cent to the illumination secured with the dark green ceiling so often seen, and naturally, the car will appear much brighter and more cheerful. If a gray tint is used, the paint should be mixed with vermillion and emerald green and reduced with white until the proper tint is secured. A gray that is mixed with lamp black has a much higher absorption than a warm gray mixed as above.

The shape of the ceiling also has a decided bearing on the illumination. The old ceiling with the deep half decks is rapidly

being displaced with a curved ceiling extending in one sweep over the width of the car.

This is a much better arrangement from a lighting standpoint than the old one because the light is not bottled up in the narrow area between the half decks. This arrangement also provide better light on the advertising cards.

The amount of light necessary and the arrangement of the outlets are matters that have received considerable attention and aroused a great deal of discussion. It is a relatively simple matter to state the minimum requirements for safety and for reading without eyestrain, but this does not really satisfy the conditions from an economic standpoint. The standard of lighting in offices, stores and industrial plants has increased materially in the last few years and this naturally influences the public's demand for higher intensities in street cars.

An average of 3.5 to 4.0 ft-candles in a car was considered very good lighting several years ago, while now there is a strong tendency to go at least 10.0 ft-candles and even higher so as to conform to the new industrial standards. This is not an unreasonable intensity, and can easily be secured with proper reflectors with an expenditure of power of about two watts per square foot of floor area.

One must not forget the fact that the 10 ft-candles measured in an empty car at rest and with lamps operating at normal voltage will be reduced to not over 6.0 foot-candles when the car is crowded and the voltage lowered as much as it is on the majority of trolley lines. The cross reflection which adds up in the empty car is also entirely absorbed in a crowded car, and due allowance should be made for this fact when estimating the desired intensity.

A much higher intensity is necessary to read comfortably in a street car than in a home or office, because the vibration and jolts of a rapidly moving car cause a rapid movement of the reading matter which is hard to follow without great eyestrain under low intensities. Many tests on the speed of vision have shown that an intensity of 10 ft-candles is necessary to read rapidly changing print.

One row of lamps on the center line of the car is the most economical way of placing the units, and an illumination test in an empty car would show a satisfactory distribution of light. The results are also fairly satisfactory to the passengers if the seats are arranged across the car. In this case the standing passengers do not cast objectionable shadows on the seated passengers. However, if the seats are arranged longtudinally the results are often unsatisfactory whenever there are standing passengers. The arms and hands holding on to the overhead straps effectually bar the light from reaching the seated passengers. In the latter case, therefore, use should be made of two lines of units, placed just inside the edge of the seats. In all cases medium density opal reflectors should be used and in no case should they be spaced more than 5.0 ft. apart. If the units are placed under the half deck it is of prime importance to use reflectors as a standing passenger is so close to the lamps that to him a bare lamp is exceedingly annoying. Bare lamps in this position also detract from the advertising value of the cards under the half-deck because of the glare.

Many accidents have occurred to passengers alighting from street cars because of inadequate light at the steps. Persons are temporarily blinded when going from a brightly lighted platform to the dark steps and many serious falls have resulted. Several methods have been satisfactorily tried to solve this problem. One is to utilize one circuit just inside the door to operate when the door opens. Another method is to set a lamp in a recess at each end of the step, each lamp operating in series with the circuits inside the car. The latter method is the better one when the construction of the car permits its use.

The principal points to consider in designing the illumination of a car, either new or when remodeling, is the value of a light finish on the ceiling, the use of a proper reflector, spacing of the lamps not to exceed five feet, and an intensity high enough not only to make comfortable reading but to attract passengers to a well lighted cheerful car.

DISCUSSION.

The papers by Messrs. Summers and Hulse and that of Messrs. Porter and Jordan were discussed together. See p. 110.

RAILWAY CAR LIGHTING*

BY GEORGE E. HULSE

Railway car lighting differs from other classes of lighting both in the methods of obtaining the energy for lighting and in the application of the lighting units.

The fact that a car is continually on the move makes it necessary to obtain the energy from a stored supply, or to generate it on the car itself. This means that the supply is limited, and that it must be utilized in the most efficient manner possible.

The lighting fixtures must be permanently secured in position, and out of the way of seats, baggage racks and sleeping car berths, which limits their application to the ceiling of the car. This factor limits the flexibility in placing the units to get the desired effect.

Much careful study has been given the matter, however, and the results obtained as exemplified by the best present practice are very satisfactory.

A series of tests extending over several weeks, was made in 1912 by representatives of the Post Office department, several of the railroads, and interested manufacturers on different methods of lighting postal cars. A few years later a similar series of tests was made under the direction of the Association of Railway Electrical Engineers, on methods of coach lighting, and it is mainly on the data obtained by these tests that the illumination values given herein are based.

GAS LIGHTING.

A large number of cars are at present, and probably will continue for some time to be lighted by gas. Practically all gas lighted cars in this country are lighted by what is known as Pintsch gas. This gas is manufactured by cracking petroleum oils in retorts or generators, and is distributed under pressure to the car yards, where it is transferred to suitable holders carried underneath the cars. The gas has a high heating and illuminating value, thus making it especially suitable for car lighting as a large supply can be carried in a small space. The principal feature of

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the car equipment is the regulator which maintains a constant pressure at the burners.

The constant pressure given by the regulator and the uniform quality of the gas permit the lamps to be made without any means of adjusting the air or gas supply to the burner.

The incandescent mantle is almost universally used with gas equipments. All new cars are fitted with it, and the flat flame lamps in old cars are rapidly being converted to use the mantle. Two sizes are in use, one giving 90 cp. and consuming 2.0 cu. ft. of gas per hour, the other giving 125 cp. with 2.5 cu. ft of gas per hour. A smaller size giving 25 cp. is used where small bracket lamps are desirable.

ELECTRIC LIGHTING

What is known as the "axle generator system" has come to be almost exclusively used for lighting cars by electricity. The use of the straight storage system, by which the current was obtained from storage batteries which were charged while the car was at a terminal has almost entirely disappeared, owing to the fact that cars were kept too long out of service for charging and were dependent on a stationary plant. A few cars are still lighted by the "head end system," in which the current is obtained from a steam driven generator set in the baggage car of the train, but owing to its lack of flexibility this system has had a limited application.

In the axle generator system the current is generated by a generator driven from the axle of the car. This machine provides current for the lamps, and charges a storage battery which provides service when the car is not in motion. With this system, the car is equipped with its own power plant, and has an ample supply of current wherever it may be in service. Such attention as is necessary is easily given during its regular lay-over periods.

The essentials of such a system are as follows:

1. A generator mounted on either the car body or the truck with some form of driving system between the car axle and the generator.

2. A storage battery to furnish current when the car speed is not sufficient to drive the generator at a speed to give the proper voltage.

3. A regulator to govern the output of the generator at varying speeds, and to charge the storage battery properly and protect it from overcharge.

4. A regulator to maintain proper voltage at the lamps.

5. Some means of keeping the polarity of the generator constant when the direction of movement of the car changes.

These conditions have been successfully met in various ways. The majority of equipments in use have the following features:

The generator is mounted on the car underframe and is driven by a belt. The generator is controlled for output at varying speeds by carbon-pile rheostat in its field circuit which gives a constant current output until the battery approaches full charge, when the battery is protected from overcharge by the control passing to voltage, or by having the charge discontinued by a meter which measures the ampere-hours supplied to the battery.

The lamp voltage is held constant by an automatic carbon-pile rheostat.

At the present there is some demand for a more positive drive than the belt, which does not always give perfect service, especially in bad winter weather. Various types of gear or other positive drive are being investigated but it is doubtful, if when all the conditions of application to the car, first cost, and cost of maintenance are considered the improvement in service will be justified.

CAR ILLUMINATION

As I have already said the location of the lighting fixtures in a car is limited to practically one position.

This makes it impossible to keep them out of the range of vision, and makes proper screening of the light source absolutely necessary. The motion of the car also makes a fairly high intensity of illumination necessary.

COACHES

Coaches are of course important as they constitute the majority of cars in use and carry more people than any other class of car.

A certain amount of general illumination is necessary, but the principal illumination is required for reading, and the lighting

system should be designed for proper illumination on a plane 45° to the horizontal, and at right angles to the center line of the car.

The lamp fixtures may be either mounted on the center line of the car on the upper deck or there may be a row on each side of the car directly over the seats mounted on the lower edge of the side deck.

The tests on coach lighting conducted by the Association of Railway Electrical Engineers demonstrated that equally good illumination results as far as distribution and uniformity go could be obtained with either type of installation. Practical consideration make the center lighting arrangement more largely used on account of the smaller number of fixtures required, and fewer lamps and reflectors to maintain. Center lighting also gives less trouble from shadows cast by a passenger's head on his own or another passenger's paper.

The spacing most used for the lamps is 6 ft., the mounting height for center lamps is about 8 ft., and for side lamps, about 6.5 ft.

Up to the present the open mouth type of reflector, of either heavy density opal or clear prismatic glass, has been employed for coach lighting.

The use of these types of reflectors with 6-ft. spacing and 50-watt train lighting lamp giving 506 lumens, or 84 lumens per running foot length of car, gives about the following illumination results:

FOOT CANDLES

	45° Plane			Horz. plane	Efficiency
	Window seats	Aisle seats	Mean	Average	Horz. plane
Heavy density opal	2.60	3.51	3.06	4.48	49.7
Clear prismatic	2.55	3.34	2.95	4.23	46.6

The lamps used in the above were 50-watt trainlight type B (vacuum) lamps having an output of 506 lumens.

The type C (gas-filled) lamp is available for car lighting purposes. While the intensity of illumination can be increased by the use of these lamps, the wisdom of the use of the clear lamp in open mouth reflectors is questioned as under these conditions it is almost impossible to get away from the effect of the high intensity filament. Even though the filament is properly screened

there are bright spots on the reflector which cause eye fatigue.

Totally enclosed units placed close to the ceiling are however being introduced for coach lighting, and these give satisfactory results as to illumination and present a pleasing appearance.

With the better grade of glass available at present the illumination values obtained with the 50-watt type C lamps (740 lumens) giving 123 lumens per running foot of car length would be about as follows:

FOOT CANDLES

45° Plane Window seats	Aisle seats	Mean	Horz. plane Average	Efficiency Horz. plane
2.18	2.40	2.29	2.82	22%

Using 75-watt type C lamp (1024 lumens) or 170 lumens per running foot of car these values would be as follows:

45° Plane Window seats	Aisle seats	Mean	Horz. plane Average	Efficiency Horz. plane
3.02	3.32	3.17	3.92	22%

It will be noted that using the same wattage the values obtained with the type C lamp and enclosing bowls are about 23 per cent lower than those with open mouth reflectors and type B lamps. To get equal illumination it is necessary to increase the wattage 50 per cent with the enclosing bowl type.

In the latter case however the illumination is of a better character and the appearance of the car is considerably improved.

In some respects however open mouth reflectors are superior to totally enclosing units as with the reflector the ceiling is not illuminated to any extent and affords a rest space for the eye which is not present with enclosing units mounted close to the ceiling.

With gas lighting the lamps are generally spaced three seats or nine feet. The best arrangement of fixture is an enclosing bowl, as open mouth reflectors are not suitable for use with gas burners. The type of bowl best suited to use with the gas mantle is one approximately spherical in shape the upper half being heavy density opal, the lower half optic ribbed. The gas mantle has a rather low intrinsic brilliancy and these ribs give sufficient diffusion to prevent any bad effects from glare.

The illumination values for a coach with such an equipment using the 90-cp. mantle with 9-ft. spacing, 87 lumens per running foot of car, are as follows.

FOOT CANDLES

45° Plane			Horz. plane	Efficiency
Window seats	Aisle seats	Mean	Average	Horz. plane
1.75	2.04	1.89	2.42	25%

With the 125 cp. mantle giving 120 lumens per running foot of car, these values would be as follows:

FOOT CANDLES

45° Plane			Horz. plane	Efficiency
Window seats	Aisle seats	Mean	Average	Horz. plane
2.44	2.84	2.64	3.37	25%

DINING CARS

Most of the novelties in car lighting are used in the dining cars. The table and its furnishing are the most important item in the car and the high illumination must be concentrated on each table. General illumination of fairly high intensity has always been found necessary so that the car would present a cheerful appearance to the person entering it. Installations with a high intensity on the tables and a low general illumination have not been found satisfactory. Generally illumination can be obtained from fixtures mounted on the center deck, either direct or semi-direct. For table illumination fixtures should be mounted over each table and no more satisfactory type of unit has been developed than that which uses the concentrating reflector with a redirecting plate under it to give the proper distribution for maximum light on the table top.

For general illumination a semi--direct fixture is now generally preferred and sufficient illumination is obtained with such fixtures mounted six foot apart using a 50-watt type C lamp.

The illumination on the table top should be from 5.0 to 7.0 ft-c. and this can be obtained by the use of a 50-watt type C lamp in the table fixture mentioned above.

SLEEPING CARS

Sleeping cars require lighting for general illumination, for

reading or working at the tables in the sections, and for illumination of the berths after they are made up.

General ilumination is obtained by center lamps placed close to the ceiling to prevent interference of the fixture with the upper berth. Small units placed in the corner of each section provide additional, local illumination for reading and to light made-up berths.

The staterooms of a sleeping car and a compartment car are lighted in the same way.

Smoking rooms have a center lamp for general illumination and bracket lamps back of the fixed seats to afford proper lighting for reading.

The passageways are lighted by ceiling fixtures, using either an open-mouth reflector, or a fixture with a reflector and directing plate set flush with the ceiling.

For lighting of the berth section of the car after the berths are all made up there has recently been developed a fixture which is secured to the seat frame and throws the light on the floor so that it is easy to find the way along the aisle after all the ceiling light has been extinguished in this section.

The present practice is to use total enclosing center lamps having a hemispherical bowl placed against the ceiling. Type C, 100 watt (1461 lumen) lamps are used, and the illumination on the reading plane probably averages 4.5 ft-c.

PARLOR SMOKING CARS

The lighting of this type of car presents a rather difficult problem, as the seats are so arranged that the occupant faces the center of the car. Best results are obtained by the use of a few center lamps for general illumination, and bracket lamps placed on the side of the car back of the chairs for reading light. Cars having a flat side deck can be fitted with reflecting units directly over the chairs instead of bracket lamps.

PARLOR CARS

The conditions in this class of car are very similar to that in the passenger coach, and the same type of installation is used, although indirect lighting can be better used in parlor cars owing to the fact that the walls and ceilings can be maintained in better reflecting condition.

POSTAL CARS

Postal cars require greater illumination than those of any other class, as the work done demands constant and arduous use of the mail clerk's eyes. A very thorough investigation was conducted some years ago by one of the large railroads assisted by various manufacturers and participated in by the Standard Car Committee of the Post Office Department. Various types of installation were tested, and determinations were made of the amount of light necessary for the postal clerks to work. From the results obtained by these tests the committee issued specifications for lighting which must be met in every postal car.

Postal cars are generally divided into three sections; the letter-distributing cases, the bag-distributing racks, and the storage space. The distributing cases require high illumination on the vertical plane of the box labels and on a horizontal plane for reading the addresses on the mail. The bag-distributing racks require high illumination on the horizontal plane, for the labels on the bag racks. The storage end requires a fair general illumination.

Initial Values of Illumination Required.

	Foot-candles	
	Minimum	Maximum
Bag rack portion:		
Center of car-horizontal	3.75	12.00
Mouth of bags, measured 18 inches from side of car horizontal	2.00	12.00
Letter cases:		
Over table-horizontal	3.75	19.00
Face of case-horizontal	1.66	19.00
Storage portion	2.00	12.00

These initial values are so set as to give proper illumination with a 40 per cent depreciation in the efficiency of the installation.

A 60-ft. postal car is lighted to these specifications by the use of 11 mantle gas lamps the 90-cp. (780-lumen) mantle being used. Metallic reflectors are used almost exclusively for postal car lighting, those having a matted aluminum surface being preferred.

These specifications in the 60-ft. car are more easily fulfilled by the use of fifteen 50-watt (506-lumen) lamps. Some installations are now being made with the type C lamp in postal cars but enough experience has not been had with this installation to determine as to whether it is entirely satisfactory.

PRIVATE CARS

A private car is a combination of several types of cars and the lighting is accomplished in the different sections somewhat as it is in the class of a car to which that section corresponds. The observation room resembles somewhat the parlor smoker, and in this part of the car general illumination is obtained by center lighting, with bracket lamps behind the chairs, or half deck units for local lighting. In private cars, however, more latitude is allowed in fixture design, and frequently the center lighting is obtained from one large fixture placed in the ceiling of the observation room.

Local lighting is provided for the gauges and speed indicating devices with which most business and private cars are equipped, so that these instruments may be read when the other lamps in the car are not in use to allow track inspection from this part of the car at night.

The dining room of a private car is best lighted by a single unit placed directly over and throwing a high illumination on the table, with local lighting for the buffet.

The staterooms are lighted with center lamps, with local lighting for the mirrors. Where berths are used, berth lamps are provided, and special reading lamps are attached to the bed posts.

All cars with vestibules have lamps over each step, directing light on the steps. A flush type metal reflector is generally used.

BAGGAGE CARS

Baggage cars do not require a high intensity of illumination but its distribution must be such that a moderate illumination is obtained in both the horizontal and the vertical planes, and the illumination on the vertical plane must be of a fair value up to within about two feet of the car roof. The reason for this is that the lading of the car is sometimes piled high, and there must be sufficient light to read the labels or marking on the packages. Glass reflectors are not desirable on account of breakage. The present preferred practice is the use of an enameled reflector of the r. l. m. type placed as close to the ceiling as possible. These fixtures are spaced about ten feet apart, and 50-watt (740-lumen) type C lamps are used. This installation will give an illumination of about 4.5-ft-c. average on the horizontal plane, and values ranging from 1 to 5 ft-c. at different heights in the vertical plane.

Baggage cars are also provided with a fixture over each door designed to light the doorway, and a baggage truck placed for loading the car.

REFLECTORS AND GLASSWARE

A number of types of reflectors and enclosing units have been developed for car lighting uses.

For cars where efficiency is the prime object, and appearance a secondary consideration, the open-mouth reflector is in almost universal use. Best results are obtained with a reflector giving the maximum candle-power at 45 degrees.

The following are the principal types of this class of reflector, together with the illumination obtained and the efficiency using a 6-ft. spacing, giving 84 generated lumens per running foot of the car;

	Average illumination on 45 degrees reading planes, foot-candles			Illumination efficiency on 45 degrees plane
	Aisle seat	Window seats	Average	
Prismatic clear	3.34	2.72	3.04	34.2
Heavy density opal	3.03	2.55	2.69	30.2
Medium " "	2.52	2.07	2.30	25.9
Prismatic satin fin.	2.44	1.89	2.17	24.3
Light density opal	2.25	1.91	2.08	23.5

Where appearance is the primary consideration enclosing units are used, and the energy efficiency somewhat sacrificed.

The following results are obtained with this class of unit using 123 lumens per running foot of car length.

Enclosing units	Average illumination on 45 degrees reading planes, foot-candled			Illumination efficiency on 45 degree plane
	Aisle seats	Window seat	Average	
Light density opal	2.00	1.78	1.90	14.6
Shallow prismatic	2.55	2.00	2.27	17.5
Reflector with light density bowl reflecting and diffusing globes	2.64	2.27	2.46	19.0
Semi-indirect	2.86	2.27	2.57	19.8
Total indirect	2.50	2.03	2.26	17.4
Bare lamp	2.15	2.07	2.11	16.3

All the foregoing are for electric light. For gas lighting the following results were obtained, the generated lumens being 120 per running foot of car.

Enclosing units	Average illumination on 45 degrees reading planes, foot-candles			Illumination efficiency on 45 degree plane
	Aisle seats	Window seats	Average	
Deep prismatic reflector and bowl	3.65	3.72	3.69	26.8
Reflecting and diffusing globes	2.74	2.34	2.54	18.4
Medium density opal globes	2.08	1.52	1.80	13.1
C. R. I. diffusing globes	1.92	1.67	1.80	13.1

FIXTURES

Lighting fixtures for use in railroad cars require special design and construction, and embody some features not found in fixtures built for other purposes.

1. They must be substantial to withstand the constant vibration to which they are subjected.

2. They must be easily removable for refinishing when the car goes through its regular shopping.

3. The arrangement for holding the glassware must be such that it can be easily applied, or removed for cleaning, but at the same time must be securely held so that there is no danger of its jarring loose.

4. They must be of suitable color and design to harmonize with the interior treatment of the car.

5. The mechanical design must be simple and all working parts must be easily accessible.

The first condition is met by careful mechanical design suggested by experience in this class of work, as fixtures built for other uses are wholly unfit for use in railway cars.

The second feature is generally covered by a type of construction in which a plate or spider is firmly fastened to the car ceiling, this plate forming the support for the socket. The ornamental part of the fixture is secured to this plate, but may be removed without disturbing the electric connections or the attachment to the ceiling.

The arrangements for holding the glassware in enclosing units must be worked out for each type of glass employed. With a large proportion of the fixtures for electric lighting, use is made of open mouth reflectors and for these, holders have been developed which fulfill the condition admirably. The ordinary type of holder equipped with set screws was quickly abandoned as being unsafe. The best holders developed consist of a spring clamp comprising a number of metal fingers which spring over and grip the neck of the reflector. In order to make the action of this spring clamp positive, a cap nut is screwed down against the spring clamp, locking the fingers against the neck of the reflector in such a manner that the spring of the clamp takes care of expansion in the glass and cushions it against vibration.

It has been found that no change in design of fixture is necessary to accomodate the type C lamp as most of the fixtures are designed with sufficient radiant capacity to accomodate this lamp properly.

The Association of Railway Electrical Engineers has recently adopted four standard lamp positions. These are the 1.5 in., 1.0 in., 0.5 in. and zero, these dimensions indicating the distance which the top of the contact point of the lamp is above the top of the reflector.

The question of suitable design is one which is governed to a certain extent by the wishes of the purchaser, but I believe that the results obtained in car lighting work compare very favorably with that in other lines.

Electric lamps are so built that the bulbs may be easily renewed, and that the sockets and wiring easily are accessible. Gas lamps are so made that they can be lighted without opening the bowl, mantles applied without the mantle being removed from the container until it is properly attached to the lamp, and no adjustments to the air or gas supply are necessary; in fact the lamps are made without any means of adjustment.

DISCUSSION

The paper by Messrs. Porter and Jordan, and those by Messrs. Summers and Hulse, were discussed together.

R. B. Ely: I should like to ascertain if gas lighting systems are being installed in new passenger coaches, and if when coaches are being renovated electric lighting systems are installed on cars

that were formerly illuminated by gas lighting. I should also like to learn whether the company Mr. Hulse represents ever considered the idea of wiring the ordinary freight car, by placing two or three outlets in the interior of the car and a suitable outlet on the outside of the car for plugging in at transfer stations. The expense of such a wiring system, it seems to me, would be small, when one considers the life of the car in comparison with the convenience and advantages to be obtained when loading and unloading. Many demands are being made for portable lighting units for illuminating the interior of freight cars when being loaded and unloaded.

L. C. Porter: Mr. Hulse said that in laying out the lighting system for postal cars allowance was made for 40 per cent depreciation in lighting. I should like to ask if he has any figures showing that so great a depreciation as that is actually present in the service.

S. G. Hibben: A very important feature of car lighting that has been advocated by the railway electrical engineers is the standardization of reflector holder positions. Men conversant with that subject realize what a tremendous difference in car illumination results from the various positions of the lamp filament with respect to the reflector, and they realize that in spite of this fact there still exists a wide variation of holder positions and a considerable neglect on the part of the manufacturers to provide suitable adjustment in fixtures to take care of different designs of reflectors and different light-center lengths of lamps.

As Mr. Hulse has stated, the committee on illumination of the Association of Railway Electrical Engineers has recommended four definite holder positions. These positions represent the distances between the top level of the fitter tip and the cap contact of the lamp base. They are designated by 0 and the figures 2, 4, and 6 representing quarters of an inch, that is, in position 6 the base contact of the lamp is 1.5 in. above the heel of the reflector, etc.

If the manufacturers of fixtures for railway cars can agree on this standardization, it will pave the way toward similar standards of design for all fixture manufacturers. The proper placing of the lamp in its accessory is vital to the improvement of the lighting industry. It is a much neglected point that I wish to stress emphatically.

Be it said to the credit of the railway electrical engineers there is less violation of good lighting practice through bare or exposed lamps in car lighting than in most other applications. Here has been learned the lesson that glare is uncomfortable, that waste light costs real money. Placing the lamp deep enough within the reflector to secure good distribution downward, and using reflectors of sufficient depth to extend down to at least the plane of the lamp tip so as to reduce glare, are essential features of good coach lighting.

For example, the Pennsylvania Lines standardize a holder position of 1.125 in. for the No. 18226 deep bowl prismatic reflector, and the distribution from the 50-watt G-30 bulb clear lamp results, in securing about 50 per cent of the generated lumens as effective at the reading level. The distribution is nearly the same with a 1.25-in. holder position, and the probability of glare is less. However, between a ⅝ inch and a 1⅜ inch holder position, there is a difference in a typical case, of a utilization efficiency varying from 43 per cent to 53 per cent; that is, merely a change of a fraction of an inch makes a difference of nearly 25 per cent in the useful lumens.

If we are to continue making improvements in reflectors, and if there is a likelihood of changes in lamps and filament construction, then it is wise to make use of adjustable holders. These will not only provide for changing accessories, but also for different spacings. I want to compliment the railway electrical engineers on this forward step, providing adjustable stems that carry the lamp sockets and establishing the four standard holder positions.

From the test figures given to-night it appears that about the best coach lighting efficiency is in the neighborhood of 40 per cent. In good factory and office lighting installations one obtains in the neighborhood of 50 per cent utilization, hence there are possibilities of better engineering in railway and street car lighting, one of which has to do with the color of interiors. Any railway maintenance man knows that cleaning is a subject for considerable ingenuity. Soaps are sought for that will remove grease, but not affect paints. Acids are desired to cut grime but not corrode metal. Paints are tried which will adhere

to all manner of surfaces, will not fade or discolor, are not browned by sulphurous atmosphere, and which will give fair reflections of light. Lighter shades of paint and lighter colors of the upper parts of car interiors will help us to move from the 30 to 40 per cent efficiency class, up into the 50 to 60 per cent class.

From the engineering point of view there is no reason why the railroads need continue to use the round bulb or G lamps. Type B or vacuum lamps can also be replaced by some of the new gas filled lamps in standard bulb shapes, particularly when the new adjustable holders are provided to prevent such lamps projecting too far out of the reflectors.

In the past we have been securing intensities of 3 or 4 foot-candles in railway coaches, and 2 or 3 in street cars. In industrial plants we have gone to standards of 10, 12, or 15 foot-candles with resultant decrease of accidents and a gain in seeing ability, and I hope that by using proper holders, gas filled lamps, lighter colors of paints, and liberal application of soap and water, we will soon approach such intensities in car lighting.

In street cars it is possible to double the useful illumination by placing reflectors on the lamps. That being true, it is strange that street car manufacturers do not install reflectors as part of the standard equipment. Some say that street railway companies generate energy at low costs, and can afford to waste it. But can they? Energy at the power house is relatively cheap, but delivered at the socket in the car is another thing. In street cars, use is made of around 1.5 to 2.0 watts per square foot, with the whole ceiling studded over with bare lamps. The loss is tremendous. Such a consumption should produce easily 6 to 8 foot-candles if efficiency converted into light that is properly directed.

E. E. Dortings In connection with the lighting of electric railway cars mention should be made of a very important matter, the maintenance of lamp outlets. It is true that the initial equipment should include proper reflectors, lamps and spacing of same and also that the ceiling and side-walls of the car must be light in color and kept clean. However, the real problem is one of replacement where lamp failures may average approximately 1 per cent of the total number of outlets every 24 hours. In the I. R. T. subway we have about 2,000 cars containing 49,000 outlets. These cars are stored at various yards and operated over

different lines. The lighting system consists of 5 lamps in series off the third rail voltage and when one lamp fails four more go out of service with it. Therefore, the problem involves replacing nearly 500 lamps each day, and all of the cars do not run to one specific terminal.

The burned out lamps are not discolored, but have broken filaments as the electric railway car gives a tungsten filament lamp a most severe test so far as mechanical breakage goes. I would suggest that the engineers of the various lamp manufacturers design a more rugged lamp for car lighting.

Permit me to mention another important matter, the method which should be employed by consulting engineers or public service commissions when specifying requirements for car lighting. For instance, the Inter-borough Rapid Transit Company is working under a specification which calls for 3 foot candles on a horizontal plane 42 in. above the floor when the lamps are operating at 85 per cent of the sub-station voltage. This specification may be correct for some railways having a great drop in line voltage due to lack of copper, and no doubt the specification was intended for this particular condition. In the New York Subway cars the average line voltage is approximately 97 per cent of the sub-station voltage and hence the lamps actually produce from 6.5 to 7.5 foot candles.

J. A. Summers: I am in sympathy with Mr. Dortings desire for a more rugged lamp, and I know that the lamp manufacturers are making every effort to develop such a lamp. Beyond doubt more care should be given to proper maintenance. It is difficult to keep a white or light-tinted head-lining clean but a cheerful looking street car is certainly in demand and better lighting with light colored-finish will aid materially in getting it.

George Hulse: In regard to Mr. Ely's question as to the equipment of new cars, it is to be noted that a considerable number of new cars are at present being equipped with gas, but of course not as large a proportion as there was several years ago.

As regards the equipment of cars which are being repaired, or rebuilt, I should say that in some instances electric lamps are

being applied in the place of gas, and that in other instances, gas lamps are being substituted for oil lamps.

As regards Mr. Ely's suggestion in reference to wiring freight cars so that the interior of these cars can be illuminated at transfer stations, the expense would, of course, be a very considerable item when the number of freight cars in service is considered. It would also be practically impossible to maintain the equipment on these cars and to have lamps in the sockets when they are needed. I believe that the requirement is pretty well taken care of by the use of portable lamps installed at points where the illumination of the cars would be needed.

Regarding Mr. Porter's inquiry as to depreciation in the illumination in postal cars, I believe that the depreciation is kept pretty well inside the figure 40 per cent. I have no figures as to the aggregate depreciation, but do know that a good reflector will show a depreciation of not over 25 per cent, in its worst condition. The postal cars have to be pretty well inspected to keep the lighting equipment in good order as the railway mail officials insist that this be done.

The adoption of standard holder positions by the Association of Railway Electrical Engineers, together with the fact that many of the fixtures are made so that they are easily adaptable to any of the standard positions, will result in lamps and reflectors being properly used to give the best illumination results, with the proper screening of the filament.

It has been found by placing a type C lamp a little higher than its theoretical position, satisfactory illumination is obtained with an increase in the screening angle of the reflector.

It should be noted that the illumination values which I have given are those on the 45° slope as the reading plane. The illumination on the horizontal plane will run from 50 per cent to 60 per cent higher than the values given in the paper.

An observation of the illumination in the Pullman sleeping cars at the present time will I think convince one that ample illumination is being provided. The illumination is about 4.5 ft-candles on a 45° plane which would mean about 7 ft-candles on a horizontal plane. As already stated, the amount of electrical power available for car lighting is limited, and it is better to use an installation which can be operated at the max-

imum efficiency than to install equipment to give higher illumination, but which, due to the limitations of the source of energy, might, for a considerable part of the time, be operated below its maximum efficiency and really delivering less illumination than the smaller but more efficient equipment.

TRANSACTIONS
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SOME DIFFICULTIES IN SCHOOL LIGHTING*

BY FRANK H. WOOD**

The requirements governing the lighting of school rooms to be used for study and recitation purposes are few in number, simple in statement, easy to justify, and it would appear not difficult to carry into effect. They are in brief as follows:

> Windows are to be grouped on the left of the pupils as seated, and directly opposite their desks, none reaching beyond the line of the front desks.
>
> They must extend to the ceiling and in area must be equal to one-fifth of the area of the floor.
>
> Their height, measured from the floor, must be at least one-half of the width of the room.
>
> They must be without transoms or unnecessary width of muntins or mullions.

It all seems simply a question of measurement and calculation involving the use of the yard stick and elementary computations. But there are other considerations and some real difficulties to meet. First of all, there is the architect, who is a very real factor in the problem. He has his troubles with us, and we with him, but we get on very nicely together notwithstanding. We could not afford to do otherwise, for we could not get on without him. The main difficulty with architects lies with their training, their instructors and teachers. They have been taught altogether too largely to take up their position outside and look in, and all too little to take their position inside and look out. We are obliged to adopt the view that the school is for the child, that it is his civic home during the best hours of the day throughout childhood and youth, that he is the ward of

* A paper read before the New York Section of the I. E. S. on May 12, 1921, by Dr. William A. Howe of the New York State Board of Education.

** New York State Board of Education, Albany, N. Y.

the State while in the public school, obliged to be there by the laws of the State, and that, consequently, the first, foremost and determining factor in the planning and construction of a schoolhouse is fitness for the pupil's use, for his comfort, health and general welfare. It is accordingly our practice in all questions involving the planning of school buildings, to invite the architect inside to a seat with us beside the pupil, and from that vantage ground, work out our problems together.

Transoms, diminutive panes of glass, the shaping and placement of windows to carry out some particular style or type of architecture, for example, must give way whenever needful to insure for the pupil every advantage of one of God's greatest and most abundant gifts to man—light.

It is not at all easy at times to overcome all difficulties that present themselves, that is,

1. To have multiple windows instead of piers in class and study rooms or when piers are necessary, to reduce them to the narrowest width;
2. To have windows extend as close as possible to ceiling, and so group them as to be directly opposite the pupils' desks without projecting beyond the line of the front desks;
3. To leave the wall opposite the windows free for blackboards so that the pupils may have the benefit of directly reflected light;
4. To keep the width of all class, study and recitation rooms within twice the distance from floor to window top. Persistent study and intelligent skillful planning can and usually do smooth out these difficulties.

The extraordinary high cost of construction that has prevailed in recent years has aggravated the situation greatly, as it necessarily entails an increase of expense to meet some of these requirements. Where the amount available is limited to an absolute fixed appropriation, and that appropriation is too small to secure what is needed, to say nothing about what is wanted, the task inevitably comes to be a hard one to solve.

OLD BUILDINGS

Our most serious and difficult problem, and at the same time probably our most important one is in dealing with our old

buildings, of which there is legion, buildings that have been with us long, many of which presumably will continue to linger with us for years to come. Some of them can be improved for temporary use at nominal expense. A few can be remodeled and enlarged but most of them will need to be replaced. Naturally enough it is in the replacement of the building that the greatest difficulty is experienced. When people look at a building that they have always known, it is apt to look to them as it always has. This is particularly true of structures that have been well maintained and present a good exterior appearance, even though in interior arrangements they may not comply with any of the statutery standards prescribed for the construction of school buildings. The general public is not informed on these points, is not acquainted with these standards, and frequently is ignorant of their existence. Moreover, the general public rarely sees the building from within.

School buildings cannot be constructed or remodeled without money which cannot be secured except through bond issue or, as in rare instances, by direct tax. A bond issue must be authorized directly by the people or as in some of our cities, indirectly through their chosen representatives. Hence, it becomes necessary to educate the people, to inform them concerning the essential qualities of a satisfactory building and to lead them to see for themselves when, and to what extent, their own school falls short of these standards. It is through such a campaign of education, intelligently and persistently carried out, that so many new, modern school buildings have come into being in recent years, especially since the present building law was enacted seventeen years ago. This is largely responsible also for the growing widespread interest in the construction of modern, up-to-date buildings at the present time.

In this connection, it is interesting to note that the existing school building program, either already adopted in cities and villages of New York State, or definitely planned for adoption, will involve an expenditure of approximately one hundred million dollars. It may be more than that as this estimate is from data which from the nature of the case must be quite incomplete.

The improper lighting of old buildings is the most common defect and usually the most difficult one to remedy. Frequently

the defect proves impossible of solution. Either the ceilings are too low, the rooms are too deep, the short side instead of the long side of the room is on the exposed wall, smoke stacks or other obstructions are found in the outer walls of the building, or it may be that these walls are structurally too weak to admit of the extensive changing of windows necessary to comply with the requirements. The projection lantern has proved a great help in illustrating these conditions, in making it possible to distinguish between good and bad, and in enabling people to visualize for themselves. Every new building serves as a fresh object lesson to help on further undertakings, the accumulative effect of which will facilitate progress in an ever increasing degree.

WINDOW SHADES

One of the most troublesome problems in connection with lighting, one that seems particularly difficult of solution, is that of window shades,—there selection, proper method of hanging and doubtless the most difficult of all to reach and solve, their systematic and intelligent use.

The window shades found in schools are almost invariably too dark and too heavy and compact in texture. The purpose controlling their selection seems to have been to secure material that would not show soil and that would wear; in short, to save expense. So great and general has been the demand for shades of this description, both in school buildings and elsewhere, that it is well nigh impossible to find satisfactory shades at local stores. One of the unanswered questions that has frequently been in the mind of the writer is this: what workable plan can be devised to make it not only possible but easy and desirable for districts to secure suitable shades at a low cost. The item of cost is one for real consideration, particularly with our ten thousand rural schools.

As already suggested, it is common to find shades that are opaque, or nearly so, instead of translucent. When rolled there is nothing to debar the direct rays of the sun. When unrolled, the light is usually excluded. The texture of shades should be such as will shut out the direct rays of the sun, and at the same time, admit the maximum amount of light without creating a glare.

Another difficulty arises from the fact that shades are commonly fastened at the top of the casing and are usually left half unrolled, not only on clear days during the hours when the sun's rays do not strike the windows, but also on cloudy days when every square inch of glass surface is at a premium. Hence the upper half of the window, which represents at least two-thirds of its efficiency as a medium of light, that portion through which the light is thrown into the far side of the room and on the blackboard,—which should be directly opposite the windows,—becomes largely useless, particularly when the shades are opaque. This problem can be much simplified by the use of approved fixtures and proper hanging.

The best method, barring possibly the single shade with patent movable fixtures, is to have shades to each window fastened midway with overlapping fixtures, one to draw up and one down.

Yet, however well the windows are arranged and however intelligently selected and hung the shades may be, the object in view will be set at naught, to a greater or lesser degree, if the shades are not given systematic and intelligent attention. Of course, this is a duty that falls directly on the teacher, and hence the teacher should make a careful study of the matter and give it constant systematic attention until it becomes a habit of action.

Now this would be an easy solution of this part of the problem if the practice to which I have alluded could be adopted and carried out, but it has not been made a common practice nor will it be made such until some concerted action is taken whereby a well defined plan is laid down to accomplish this object, and is then given careful, intelligent, persistent supervision under the direction of a central authority.

INTERIOR FINISH AND TRIM

To one who has had either the experience or a favorable opportunity of observation, the forbidding appearance of the dark gloomy school rooms that used to be found almost everywhere, and still predominate in many localities, will ever remain a vivid recollection of the seamy side of school life as it was, and to a large extent, it still lives. It is picture that reflects no sparkle of brightness, no traces of beauty. With walls and ceilings,

either of wood stained dark or painted a dull lead, or of plaster finished in like colors,—anything cheap, easy to apply, dirt absorbing but Pharisee-like, not dirt disclosing—it is not strange that even light itself seems to shun such rooms.

Slowly our people are coming to recognize the fact that we must have suitable light-reflecting wall surfaces in order to have properly lighted rooms, as well as rooms that are pleasing and attractive. We are coming to understand that dark, dull walls will not reflect light but instead, will absorb it, that rooms with insufficient window area can be made lighter as well as brighter and more cheerful with suitable wall and ceiling finish, than rooms amply provided with windows but having dark non-reflecting wall surfaces.

The large amount of wall area set apart for blackboards makes it particularly needful to guard against other light-absorbing surfaces. Further, aside from the teacher's blackboard in front, it has been the practice of the New York State Board of Education to limit blackboards to the side opposite the windows. For this and for other reasons, we feel that this is an allowance that should not be exceeded.

ORIENTATION OF SCHOOL BUILDING

The proper orientation of the school building has not been easy to secure. However good progress can be reported in these later years. School boards and architects are giving attention to this problem as never before, particularly the latter, as they are well aware that every set of plans submitted for approval is to be considered and criticised from this standpoint, as well as the points specifically mentioned in the Building Act itself,

It is not infrequently difficult—at times impossible—to acquire a site in which the long axis of the buildng will run north and south as is needful in order to light the school rooms from east and west, as is particularly desirable. Then too, in comparatively small buildings of the usual square type, it takes persistent study and skillful planning to limit the admission of light to these two directions. While contrary to our desire and purpose, it is at times necessary to approve north and south light in some rooms other than those set apart for drawing, science work involving the use of the microscrope, and other lines of special

work. On the whole, however, standards adopted for the orientation of school buildings have proved both desirable and practicable and the general enforcement of them necessary.

ARTIFICIAL ILLUMINATION

It is interesting and gratifying to note that there is a growing tendency to use semi-indirect lighting in the artificial illumination of school buildings, though it must be regretfully added that the fixtures commonly found are still the direct type. This leads to the making of an explanatory statement.

Just prior to the long summer vacation, it is proposed to issue a general circular of information and advice to trustees and school boards on points relating to the renovation and improvement of school building. If this plan is carried into effect, we will want to include a concise illuminating statement regarding the artificial lighting of school buildings and would be pleased to have the Illuminating Engineering Society submit such a statement for insertion.

It has been our endeavor to direct attention to the most common difficulties that are met and must be overcome to secure satisfactory, natural lighting of school buildings, and also in so doing to point out the directions that our efforts are taking. This whole matter has been a growth and development—as indeed is education itself—and all matters pertaining to it. We live under a democracy. The people rule, as they have a way of informing us in no unmistakable fashion, when they become dissatisfied with the acts of their representatives, of which fact we have had an impressive illustration within the year. If water, therefore, will not rise higher than its level, we must either raise its level or overcome resistence. In other words, a people must be trained and educated. "A free people must be an educated people." It is needful to proceed by steps rather than by leaps and bounds. To do otherwise, is to invite reaction and retrogression, as has been strikingly illustrated in certain educational legislation in recent years. All agencies, therefore, that are designed to educate, to enlighten, to lift to higher levels in ways of living, and to advance the happiness and well-being of mankind are to be hailed as agencies of civilization—messengers of the Almighty. Such an agency is the Illuminating Engineering Society, at whose courteous and insistent request

this paper has been hastily prepared.

On the title page of your TRANSACTIONS, I find this statement, "Founded in 1906 for the Promotion of the Science and Art of Illumination." A high and important aim and purpose is herein expressed, which the fifteen years of your existence have seen carried into effect, I dare say, far beyond your original expectations and hopes.

Within the month one of the chief consulting architects of the country from the mid-west, in a personal interview at the New York State Education Department, stated that in his judgement the findings of the Illuminating Engineering Society were the best guide in artificial illumination with which he was conversant and that he, himself, was governed by them.

Some years ago your recommendations were also adopted as the rule and guide of the New York State Education Department in the artificial illumination of school buildings, as may be seen by referring to our building code, page 38.

One has, therefore, but to contemplate how many millions of children are now housed and are hereafter to be housed in schools where the standards prescribed by your body govern and control, to have some adequate conception and appreciation of the importance and far-reaching influence of the constructive work that has already been accomplished by the Society.

It is indeed a gratification and satisfaction to have this opportunity to express this word of appreciation and to give assurance that we deem it a duty as well as a privilege and pleasure to co-operate with you to the extent of our ability in spreading this "gospel of light."

DISCUSSION

DR. WILLIAM M. HOWE: I have been impressed so often with the fact that so many of our children are being permitted to acquire ocular defects so soon after admission to school. While we are correcting thousands of these defects year by year, it is unfortunately true that practically as many thousands are appearing each year on the scene. I hope that you, as experts in matters of lighting, may be able some day to tell us what is normal light for a normal eye; what is a normal distance for use for a normal eye; and what is a normal angle for use for

a normal eye. I believe that your work is, and should be, very closely articulated with our general program of health work in schools. I believe that in time any school service that does not prevent most of these ocular defects, with which we are meeting so often, will be considered inefficient and derelict in its duty to school children. There is something intrinsically wrong in any educational system that permits from eight to fifteen per cent of our children to acquire defective vision within the few years of their school lives. Few children, as you may know, are born with defective eyes.

What is wrong? Are we sending our children to school too young? Are we exacting of them too much close application in the use of their eyes while the eye is in its most delicate and plastic state? Are we subjecting them to bad lighting conditions? Are we permitting their eye to become so fatigued as to be of immediate and ultimate injury?

Personally I feel there is a combination of these and other contributing causes. In the department we are intensely interested in the prevention of physical defects. While last year we had more than 141,000 corrections reported to us from the schools in New York State, exclusive of New York, Buffalo and Rochester, it is safe to say that practically the same number of new defects will appear this year. Greater and more intensive efforts must be made to prevent physical defects among our children. It offers to us our greatest opportunity to render to them the best possible health service. In so far as this preventive work applies to vision, you, as experts in lighting, can and should do much to normalize, as it were, the lighting of the buildings in which our children are housed. There is no doubt in my mind that many of the defects with which we meet are due to bad housing conditions. So far as these conditions pertain to the eye I can think of no one thing that is so contributory as that of bad lighting.

Not so long ago, our attention was called to two rooms in a rural school in which there were 75 children, 48 of whom had some degree of defective vision. That little building was beautifully situated under some elm trees, the branches of which had grown over and shaded the building,and the window space was only 60 per cent of normal. The children who sat nearest to the

light suffered the least, those farthest away from the light suffered the most. It appeared to be a matter of quantity and of distance from the window. The eye away from the window suffered more than the eye near the window. It was a forcible demonstration—a striking one—of the evils of bad lighting and of the necessity of good light well distributed. This condition, under the direction of Mr. Wood, was corrected and the eyes of the children rapidly improved. We have failed in the past to appreciate fully the close etiological relation existing between many physical defects and bad building conditions.

In our work in the Department, of which we are thinking as health service work, we subdivide it into eight divisions. That of school buildings and grounds is presided over by Mr. Wood, the author of the paper of the evening. He has direction—not only of lighting of school buildings but the ventilating, the cleaning, the general sanitation of buildings and premises. He is rendering to New York State a most valuable service.

As a Society and as individuals, you ought to keep more in touch with the activities of the director of school buildings and grounds. In his paper to-night Mr. Wood deals naturally with the subject of lighting. Other features of his work are equally important and influential in their relations to physical and moral health.

We are coming to believe more and more that there is something inherent in sunlight that is largely contributory to health. This thought is being utilized in dealing with tubercular conditions such as bone tuberculosis, tubercular arthritis and tubercular peritonitis. It has been found that by exposing gradually the surface of the body to the rays of the sun to an increasing degree that a something is absorbed or at least taken into the system which destroys the activity of the tubercular bacillus. We know that a green plant placed in the cellar or deprived of the light fades, withers and dies. It is just so with the human body. It must have day light, the rays of the sun to thrive.

Whether you people as scientists will ever be able to create artificially this particular kind of light, with its inherent properties, is indeed a great problem. You have, of course, produced a physical daylight but has it the same wonderful therapeutic properties as God's daylight.

We know that the most destructive force we have to-day against germ life, is that of the sun's rays.

We know that radium, or its emanating rays as well as the X-rays exert a curative influence over certain diseased conditions, such as cancer, that may be of germ origin. But we also know that these powerful agencies must be used in a limited manner, less they destroy healthy tissue. There is something superhuman in light, both solar light and artificial light and the last word has not as yet been spoken. I believe we are just entering a wonderful field for the investigation of the influence of light on the internal mechanism of man. I believe it will be found ultimately that a normal light is essential to normal human growth and to human functions, as it is to vegetable life. I feel that we have failed to appreciate the true relation, the real dependence of human life on light. It is a great problem of life, of growth, or even of existence. It has much to do with this wonderfully complicated machine, in which God in his wisdom has placed our soul.

I believe the time will come when we will measure, in more definate terms and utilise in a more practical manner, this real influence of light.

I have spent most of to-day in conference with a committee of the National Health Council. This organization has $200,000 with which to make an intensive study of health conditions among school children in some selected municipality in this country. It purposes, I believe, to include all phases of health. It would seem that your Society, or at least your interests, ought to be identified with this important piece of health work. Dr. L. Emmet Holt of this city is an active member of the Council. It might be well for some of you people to get in touch with him.

D. McFarlan Moore: Until a few years ago, school rooms and school buildings were used comparatively infrequently at night. But to-day all that has changed, due to the increasing prevalence of night schools, together with the fact that school buildings are used for civic work. The public at large is vitally interested in the lighting of all school buildings.

If an architect is remiss in his work, it means that the work of the illuminating engineer is that much more difficult. And con-

versely, no matter how well the architect may do his work, if a poor illuminating engineer is employed, he can easily destroy the work of the best of architects. And yet, perhaps, it is not the beauty of the building that should concern us most, but rather we are concerned in the destruction of the eyesight of children. The co-operation between the architect and the illuminating engineer is absolutely essential in order to bring about the desired result. We had hoped this evening to have a representative of the architectural profession to discuss this important subject from the viewpoint of the architect, but he has been detained. However, one of our past presidents and one of our most prominent illuminating engineers is with us and he will discuss the subject from the viewpoint of the illuminating engineer.

G. H. STICKNEY: The message of Dr. Howe and Mr. Wood is certainly inspiring to the illuminating engineers who have been working more or less altruistically in this field of lighting which is of such great importance to the country but relatively non-productive in a business way. It is gratifying to see the efforts of the Society thus appreciated and supported in such a way as to accomplish large practical results. With the realization that we are making good progress, we can go ahead with renewed determination.

This is not the first occasion on which we have co-operated with Dr. Howe and the School Hygiene Association of which he is president, but I have learned to-night for the first time, of the strength of the influence which they are exerting in behalf of better school lighting.

The movement is making good progress in other states besides New York. For example, the Wisconsin authorities are preparing to apply the I. E. S. School Lighting Code throughout that commonwealth.

I have been asked to discuss the question from the standpoint of the illuminating engineer. In line with my experience, having comparatively little experience with daylighting problems, I am likely to emphasize those of artificial lighting more than their relative importance might prescribe. The recent activity in industrial lighting rather suggests a comparison. May we not consider the school as a factory, of which the pupils are the raw

material in the process of being made into useful citizens, in other words, our most precious material and our most valuable product.

With this conception, it is evident that our school facilities, of which lighting is one, should be the very best possible.

"Seconds" in a factory, represent material which for one reason or another has been marred in the process of manufacture. The manufacturer does not like them; they sell for less, and may represent a loss; he withholds his trade mark from them. If too much marred, they are scrapped.

It is a pretty serious matter when we produce "seconds" in our schools. We cannot scrap them. Outside of the individual losses, the whole nation suffers.

Where is the great value of the training if it produces poor eyesight to limit its application?

In the last three or four years industry has come to appreciate the value of better lighting as a means for increasing production, and raising the quality of the product. Now a workman in a factory has occasion to repeat an operation many times until he becomes skilled in it, and does not need to observe as closely as during the learning period. But the pupil usually passes on to another operation before reaching that point. His work continually requires close visual application .

The experiments of Drs. Ferree and Rand (Effect of Variations of Intensity of Illumination on Functions of Importance to the Working Eye, Trans. I. E. S. Vol. 15 No. 9 page 769) reported at last year's convention, indicated that strong illumination was especially beneficial in facilitating clear vision of astigmatic eyes. I believe it is quite difficult to assure correct refraction in the growing eyes of young people. So that strong illumination is one of the essentials of avoiding eyestrain in schools. Needless to say, such light should be diffuse and free from glare.

In view of all these considerations, it is obvious that school rooms should be better lighted than factory work rooms or offices where corresponding work is done. My observation is that reverse is true, and that illuminating engineers are not succeeding in getting as good artificial lighting applied for school children as they are for workmen.

Perhaps the element of business initiative is largely responsible for this condition, but in a large measure it is due to the fact that schools have in the past been regarded as daylight plants. But artificial lighting is becoming a more and more important factor. In large cities, high buildings cut off light, so that lamps must be used more or less in the daytime, while night schools are becoming more common and are an important factor in the Americanization of the foreign born.

Even from a selfish standpoint I would like to enlist the interest of the lighting industry with the argument that pupils from well lighted schools will demand better lighting in all other activities.

I will not attempt to go into detail as to principles, and methods of school lighting, as they are already well treated in the Society's School Lighting Code. (TRANS. I. E. S. 1918 Vol. XIII No. 3, page 187). This covers both natural and artificial lighting.

Daylight is of course to be preferred when and where it is available, but to my mind the greatest element of superiority of daylight over good artificial lighting is quantity. The nature of the radiation is not widely different from that of artificial light. We can secure good diffusion of artificial light and usually better control of distribution than with daylight.

At equal intensity artificial light is regarded as superior to daylight so far as seeing value is concerned, and some lighting codes require a higher minimum for natural light.

When we hear "over lighting" charged against artificial lighting we recognize it as the glare of an improperly designed installation rather than excessive quantity.

Therefore the real problem of artificial lighting of schools is due to the expense of providing a comparable amount of light.

The corridors and stairways of a school do not demand any great amount of light. One foot-candle should ordinarily render them safe, and two to three foot-candles make them attractive and cheerful.

The class rooms, libraries, drafting rooms, study rooms, and work rooms, require more light. Work rooms can well follow the practice recommended for corresponding classes of industrial work rooms, concerning which suggestions are made in the I. E. S. Industrial Lighting Code (to be reprinted in the near future) and in trade publications.

Blackboards should have dull rather than glossy surfaces and should receive special treatment.

For reading, writing, etc., the requirement corresponds very closely to that of office lighting. We are commonly providing twelve to fifteen foot-candles in clerical offices, with a tendency to employ semi-indirect equipment when there are light ceilings.

In conclusion, I feel that I voice the sentiment of the illuminating engineers in saying that we are more anxious to promote better lighting in schools than in almost any other field, and far beyond the influence of any possible commercial prejudice.

M. E. SIEGEL: We have about 2000 rooms in our night schools which are used for four or five nights a week. We have been greatly concerned with the problem of lighting as we have with the problem of furniture. In general the lighting of our schools is as good as is found in any part of the country. We have competent architects and illuminating experts but there is a division of responsibility. The Department of Education plans the lighting but this must be approved by the Department of Water Supply, Gas and Electricity, which also supplies the lamps. Then again we face the problem, which we all face, of upkeep Fixtures are not cleaned properly by the janitors. Then there is the question of replacement. The result is that lighting in our evening schools is not as good as it should be.

It certainly would be helpful if this organization would take an interest in the lighting of the night schools. I do not know whether you have given very much thought to it. We have recently made some tests of the lighting and the maximum lighting we found was what you set up as the minimum. The maximum seems to be two and two and a half foot-candles. I should be glad to see this increased to eight and ten. If according to a previous speaker that is not too good for an office, it certainly is not too good for a class room used at night.

I should be happy to have you visit our schools and help us in any way you can. We have a committee representing civic organization for the purpose of improving lighting in the school buildings, but I think it is important that your Society should arouse public sentiment on this important matter. I welcome co-operation.

Norman Macbeth: The old problem comes up in regard to school lighting—the appropriation. I recall a meeting here within the past two years when it was brought out that lighting in the schools could be considerably increased if parents would furnish the children with a little more underclothing and the temperature of the schools could be kept lower than was general. In other words, the heating of the schools cost more than lighting. It is a pity that schools should be improperly lighted when it would cost less than one tenth of one cent per hour per pupil. Lighting costs money. But a far greater return is always made than is represented by a similar expenditure in any other school necessity.

Dr. Howe, in speaking of the value of sunlight, referred also to daylight, and used the illustration of a plant taken from sunlight into the darkness of the cellar. I believe there are some conditions due to sunlight that are not present with daylight. If you pay any attention to lawns, you know that you have to get a certain kind of lawn seed if you have shade trees. This shaded grass will get daylight but not sunlight. It may be that the ultra violet and the light of shorter wave lengths have therapeutic qualities that we do not get with daylight.

Mr. Stickney referred to the fact that all school room interiors can be more satisfactorily lighted, as far as the distribution of light is concerned, with lamps than with the light from the average windows. I agree with him that there is a great deal of unsatisfactory daylight. What I believe is more discomforting, however, is the sky brightness within the range of vision. There is a building on 42nd Street where they have windows from the ceiling to the floor; the tenants say that they have a great deal of difficulty with daylight. The trouble is not daylight distribution, but the sky brightness which they are always facing.

On the question of costs—I want to give an illustration that may be applied to schools. I recently found a statement of the cost of various items in stores. We know that good lighting will increase the sales possibilities of a store. More goods will be sold if the customers can see the goods than if they went around in semi-darkness. If you double the lighting intensities in a store at double the cost, you need only show a saving of less than ten per cent in the sales cost, to more than make up for the ad-

ditional cost of lighting. This store with twice the intensity need only sell the same amount of goods with 90 clerks where formerly 100 were required. Your may have an expenditure of ten thousand dollars for lighting, but the saving due to 100 clerks less will more than offset the added cost of lighting. The same thing applies to schools. It is up to the school authorities to consider the question of proper lighting first and the appropriation afterward.

M. E. ZINMAN: I was formerly a teacher of shorthand in the evening schools in Brooklyn. Evening school pupils work hard all day, rush home, get a bite to eat and then have difficulty in getting to night school on time. Everything should be done to make them comfortable. But, unfortunately, due to circumstances that are perhaps beyond the control of those in charge of evening work, the young students are frequently uncomfortable for the entire evening. For instance, they must sit in seats that are made for pupils five to ten years younger than they. In addition, the lighting (I speak of those schools that I have observed and in which I have taught) is very poor. Sometimes the lamps wear out and it is difficult to get others to replace them. Frequently the light-sources are so arranged that when the pupil writes several shadows of her hand fall on the paper. If the room is crowded many pupils must face a most unpleasant glare for two hours at a time. From many parts of the room it is impossible to see the blackboard writing on account of the glare.

The teacher too, suffers much on account of the light constantly striking her eyes. At times this is so bad that it materially detracts from her efficiency.

A careful investigation should be made of this situation as it is probably one of the most potent factors in causing the decrease in attendance which takes place in large numbers very soon after each term begins. Mr. Siegel, Director of Evening Schools of the City, will probably verify my statements. I presume the lighting problem must have caused him a great deal of anxiety in the past. I know that he is doing everything in his power to remedy conditions. He has the teachers behind him and anything he suggests will receive their hearty co-operation.

HOWARD LYON: The Chairman was kind enough to invite strangers to add their contribution to the discussion. I was very much surprised recently on directing an inquiry to the National Educational Association's Secretary, to learn that no action had been taken at any time by that Association on the subject of the character of paper used for school books. That seemed to be most surprising for invariably a child lays a book in any position which the desk supports and he may be getting all sorts of reflection from the paper. Such reflection is exceedingly harmful and annoying and puts us old people to sleep. It is possible to print school books on paper of the character used in the TRANSACTIONS of the Illuminating Engineering Society and it seems to me that such paper would contribute materially to the comfort and welfare of children.

I was very much interested in Dr. Howe's quiet philosophy on the subject of health. As he was speaking, various things he said suggested a lot of ideas to me. In speaking of the therapeutic value of light, I wondered whether we are not accustomed to dwell too much on defective conditions rather than on the positive advantages of certain good conditions. When we take into account the pleasure which we get from sight, even a glance out of the window, from the smell of the woods and of the air in spring, from taste, etc., one might wonder whether it is not the absence often of such things that affects the health of children.

I think it is a common experience, if one is depressed and unable to carry on his normal thinking, that he may walk out on the porch and hear the song of a bird, or smell the air, or watch the sunset, and go back to work with increasing earnestness and vigor. It seems that the effect of the senses must have a very powerful influence on health. Would it not be well to emphasize positive influences rather than negative?

I was interested in Dr. Howe's allusion to a possible therapeutic value of light, and I think he and one other speaker suggested that it might not be the thing we call light but something associated with light to which the eye is not responsive which after all has an important effect.

If you will pardon just a bit of personal experience, I wish briefly to describe some experiments which I carried on with a

young man of my acquaintance. I started several years ago to investigate the pressure of sap in trees, especially as it was awakened in the spring. Very marvelous discoveries grew out of our investigation, showing that something that comes from the sunlight is the predominating factor in causing the flow of sap. We had pressure gauges attached to trees and noted that just the passing of a cloud had a marked effect. The mercury in the tube would fall two or three centimeters in a minute by the passing of a cloud or some other condition of the atmosphere. The trees were as responsive to a something from the sky as a person of sensitive nature is to a turn of conversation. This is a most remarkable fact concerning light or rather that which is associated with light. The black birch tree often developed a pressure of over 40 pounds to the square inch.

I want to speak just a moment of rays that are associated with light, and are not light in the usual sense. Following the experiments narrated above, a physicist who was attracted to the results carried out the investigations still further. He proved that the branches of the trunk of the tree were not the source of pressure. He cut off a black birch tree a few feet above the ground and found the same response to something from the sky in the capped stump. However, he was not quite satisfied with that result and even connected a manometer to a severed root. He noted that the pressure increased precisely as though the tree was connected with the root. This pressure developed even when the ground was frozen and covered with a layer of ice. Something associated with light affected the very end of the root.

There has been a good deal of fake theory presented in regard to the therapeutic value of light, but I believe that such phenomena suggests the desirability of serious investigation by the Illuminating Engineering Society of the relation of light to health. I feel convinced that there is a further important function of light other than that of good illumination. Perhaps it is due to some invisible obscure way.

If some ray included in sunlight can penetrate several feet of earth and cause activity in root cells it seems quite likely that similar rays can penetrate the human body and possibly have some marked effect. Surely our experience indicates that health is related closely to abundant light.

Dr. M. P. Motto: I am here to-night to steal some of your thunder. At the New York Post Graduate Medical School and Hospital, with which institution I am connected in the department of Ophtholmology, I have realized how, in a measure, your work is closely associated with ours; for the reason that our aim is the conservation of sight. Let me say that your splendid meetings have helped us a great deal in our work, and I feel greatly repaid for my attendance at the past three meetings, and, which have furnished me with some splendid new ideas.

In our department we see about seven thousand new patients a year. In going over the statistics of the last year, I found that 75 per cent of those cases were errors of refraction ranging from 0.25 of a diopter of simple myopia to 24 diopters of myopia. We have some patients coming to us that are unable to read the top letter "E" of our testing chart, that should be read by a normal eye at a distance of 200 ft., and are only able to distinguish it a distance of 3.0 ft. Many of these cases are children from the New York Public Schools.

So it is evident that the alarming increase in eye defects must be attributed to other causes outside of pathological and faulty postures. And, it was left to you men outside the domain of medicine, to lead us to one of the most prolific causes of eye-strain, and that is, poor illumination.

And speaking of lighting, I well remember when I was in Cleveland a few years ago, I had occasion to go through some of the schools there. I was indeed surprised at the poor illumination of those ancient buildings. Some of the rooms had one or two gas lamps, and I wondered how the children could do justice to their work, and why there were not more cases of defective vision.

One of the speakers this evening said that his work was in a measure altruistic. Has that speaker ever stopped to consider how much of the doctor's work is altruistic. If it were not that they were willing to do that sort of work, it would be left undone. Who would do it, if not they? And so you men who have shown such a fine spirit in bringing forth this subject of proper illumination will be productive of a great deal of good which cannot be computed in terms of dollars and cents.

In your propaganda for efficient lighting I think you will find the Ophthalmologists will be with you. You are doing a mighty fine work in this respect, and I think the field is just in its infancy. You have a lot to do for the country and I think you have started in the right way.

The medical profession, I am sure will also be behind you, because if sight is not preserved surely most of the happiness of life will be cut short.

You will be surprised how the average patient that comes over to the New York Post Graduate Hospital takes sight. He is the most unappreciative of any patient I know of. They do not know what good vision means. They have never learned to see things right and they are satisfied, if they only see the 20/200 line, and think it is normal vision. If they see something round and tell you it is oval, they think it is normal. If they go to the movies and have to go to the front seat, they think that is all right. They tell you they don't want to see better. They have been accustomed to it, and they think they can get along without better vision. The first thing they will ask you is whether you are going to prescribe glasses. Truly it is not our business to put glasses on people who do not need them; but you can see the attitude of the patient. If we have to go on an educational campaign I think we ought to have some help from this organization, which is on a campaign that is going to mean so much for the growing population, to the children, who really need it. Those children in the east-side districts that are undernourished and where vision is vitally important are especially in need of your assistance.

May I thank you for your kind attention. I feel as though I am an intruder here, an outsider to get a few points from you that will be of great assistance to me in my work.

SECTOR DISKS AND THEIR CALIBRATION FOR USE IN PHOTOMETRY

BY F. E. CADY*

At the present time a photometric laboratory is not considered completely equipped without a set of sectored disks. They have become more and more necessary as light sources of higher intensity have appeared. As the value of any photometric measurement where a sectored disk has been employed depends directly on its transmission, calibration of these disks becomes a matter of some moment.

The law of the disk (Talbot's law), states that as far as the eye is concerned, the luminous flux reaching the photometer head bears the same ratio to the flux incident on the disk, as the open sector part of the disk bears to 360 degrees. Prior to 1906 this law had been accepted as verified for white light by the work of Lummer and Brodhun and of Ferry for all openings of the sector down to 24°. Ferry, however, raised a question about its applicability in the case of colored light which was settled by the comprehensive investigation of Hyde[1] who extended the verification within a probable error of 0.3 per cent., to an opening of 10° for white light and also showed that the law holds for red, green and blue light within a somewhat larger error. Since that time it has been generally accepted that the law of the disk holds and they have been constructed with openings varying from 300° down to 2°.

Sector disks may be divided into two broad classes, those in which the open sectors have fixed dimensions while the disk is in rotation, and those in which the open sector part may be changed during rotation. The former are more largely used in ordinary photometry, the latter in illuminometry and spectrophotometry.

CONSTRUCTION.

Of the first class, the most common form is a disk about 30 or 40 cm. in diameter, having open sectors. The radial dimensions of the sectors need be only a little larger than the size of the photometer-head screen since the disk can be placed as close to the photometer head as desired. The first disks used in the pho-

* Nela Research Laboratories, Cleveland, Ohio.

[1] *Bull. Bur. of Stds.*, 2, p. 1, 1906.

tometric department of the Bureau of Standards had six open and six closed sectors symmetrically distributed in order to reduce the speed of rotation necessary to avoid flicker. By the use of covers which closed the corresponding number of open sectors, one-half, one-third, or two-thirds of the total transmission could be obtained from a single disk.

It was thought that a disk could be constructed by making use of two disks which could be fixed so that the solid sectors of one would cover part of the open sectors of the other and thus give in one instrument an infinite number of possible transmissions. Since two of the previously used type of disk when placed together would be limited in range from 50 per cent. transmission to zero, Hyde, then at the Bureau of Standards, designed and had constructed a disk in which the solid sectors of the two parts were fitted with vanes which moved like the parts of a fan and enabled a total opening of considerably more than 50 per cent. A graduated scale on the rim and a set screw made it possible to fix the two parts at any desired transmission within the range. It was found, however, when the instrument was calibrated, that it was very difficult to set the opening as accurately as a fixed opening in a single sectored disk could be calibrated.

Recently disks have been placed on the market having four open and four closed sectors symmetrically distributed. Four of these disks having transmissions of 50, 60, 70, and 80 per cent. respectively may be combined in pairs to give 10, 20, 30, and 40 per cent. transmissions. Thus a 60 per cent. disk is one having openings aggregating 60 per cent. of 360° and closed parts aggregating 40 per cent. Similarly a 70 per cent. disk has 70 per cent. open and 30 per cent. closed portions. If, then, the 70 per cent. disk be placed against the 60 per cent. so that the closed portions of the 60, lie wholly within the open portions of the 70, the parts of the 70 not closed will aggregate 30 per cent. of 360°. Combining the 50 per cent. disk with the 60 per cent. gives a resultant transmission of 10 per cent., etc. One of the advantages of this arrangement is, that if two of the disks are placed together, while the transmission is decreased, the relative number of open and closed portions is doubled and the tendency to flicker, with low transmissions reduced. Another advantage lies in the fact that in the construction of the disk it is easier mechanically to pro-

duce a straight edge by filing where the opening is large than when it is small. On the other hand, it is obvious that an error in filing the edge which would be negligible in a large-opening disk may be very appreciable when that disk is combined with another to produce a small-opening effect. The method devised by Hyde,[2] of making the sectors of strips of phosphor bronze gives results of considerable accuracy, particularly for the disks of low transmission. The method is as follows: The disk is first cut roughly for the given number of openings which are made several degrees larger than the desired angle, little attention being paid to the exact amount and the straightness of the edges. The phosphor bronze strips are then cut to the right length from material about 1 mm. thick which has been found to give rigidity and still not be bulky. They must be wide enough to overlap the edge and leave sufficient room for a small slot to permit of final adjustment. The strips having their edges bevelled, are drilled and slotted at the ends and middle. The whole set, twelve for a six-opening disk, are then clamped tightly together and the bevelled sides ground to a straight edge by rubbing on a properly prepared surface plate. After grinding, the strips are mounted in place with the screws loose. A template is prepared which has a circular plate fitting accurately the hole in the centre of the disk and provided with an arm which extends to the periphery and carries on a line forming a radius of the disk, two cylinders, one near the periphery, the other near the centre, with their axes perpendicular to the line. The distances from the centre being known, it is easy to compute the cylinder diameters necessary in order that the strips shall just touch their circumference when the angular opening is correct. The cylinders can be made to the desired diameters with sufficient accuracy on a good lathe. With the template in place, the strips are moved until they come in contact with the two cylinders and are then clamped in position by means of screws working in the slots. The strips can be blackened chemically and hence the use of paint is unnecessary. As an illustration of the accuracy which may be obtained by this procedure, reference may be made to a disk prepared for this laboratory having four 1° openings, the transmission of which was found to be within 0.2 per cent. of that intended.

[2] *Astrophys. Jour.*, **35**, p. 263, 1912.

Before calibrating disks they should be examined to see that the edges of the sector openings are perfectly clean, and, if painted, that the paint is applied uniformly. The edges should be bevelled to avoid the effect of possible reflections and any evidence of non-uniformity of paint along the edges should be removed. This is particularly important in the case of disks with low transmission, and for the disks previously mentioned as used in pairs to produce low transmission. It is best to have no paint at all on the edges, the latter being blackened by some other means. As has been pointed out, this is easily taken care of where the phosphor-bronze strips are used.

Another precaution to be taken before calibration, is to see that no light is reflected from the surface of the motor used to rotate the disks. A motor for this purpose which the writer has found very satisfactory is rated at 3,000 r. p. m., one-sixtieth of a horsepower, and has a cylindrical case about 10 cm. in diameter. The top of the motor is dull black and is fitted with an upright thin metal strip which is blackened and placed so as effectively to prevent any reflected light from the surface reaching the photometer-head screen.

CALIBRATION.

It might be thought that the most direct and feasible method of calibrating sectored disks would be by means of the circular dividing engine or comparator. But the difficulties of orienting the disk on the machine, to say nothing of the large number of readings necessary to cover only a limited number of points along the edges, makes this method exceedingly laborious and not practicable except for the purpose of checking. It has the further objection that the disk is not calibrated under the conditions under which it is to be used. For example, the disk is measured while in a stationary position, but in use it is rotating. Fortunately, straight photometric methods are available, which will give an accuracy up to the limit of the photometric setting.

In their verification of the law of the disk, Lummer and Brodhun used a method which may be applied to the calibration of a 180° disk and by extension to a 90°, 45°, etc. They placed two incandescent lamps of approximately the same candlepower at one end of the photometer and one lamp at the other end. The two lamps were then adjusted in current until each produced approxi-

mately the same illumination on the photometer screen. Then both were burned at the same time and the 180° disk was placed so as to intercept the light from them, and a balance was obtained by moving the third lamp. If the process is repeated but the 180° disk is rotated while each of the two is adjusted, the 90° disk can be put in when both are burning. This method has the advantage of eliminating or reducing to negligibility many errors such as those due to the inverse-square law, stray light, variations in the photometer ways, scale, etc. It has the great disadvantage of limited application, that is, to disks which have openings in the ratio of two to one, and further admits of the possibility of adding up errors. One step can be eliminated, that is, the 90° disk can be calibrated directly, by using two lamps on each side of the photometer.

If a sufficient variety of disks is available, the so-called "cascade" method of calibration may be used. This method consists in a measurement of a disk of lower transmission in terms of a disk of high-transmission or vice versa. Thus, if the 180° disk is known, the relative value of the two halves can be determined by measuring one against the other, and their individual values found from their ratio and their sum. A 90° disk can then be compared with the two halves of the 180° disk and again its parts determined relatively and in terms of the whole. The principal objection to the "cascade" method is the possibility that the errors of measurement may be cumulative.

In these laboratories there are two sets of fixed sector disks with total openings of 300°, 270°, 240°, 210°, 180°, 90°, 36°, 12°, 6°, 5°, 4°, 2°. All of them except the last three have six openings and by means of three cover plates it is possible to get one-half, one-third or two-thirds of any of the six-opening disks. These disks have been calibrated by the "cascade" method starting with the 300° disk which was measured directly using the inverse-square law as follows: Two oval-anchored carbon-filament lamps at voltages to give a color match were used as light sources. With one as a standard, and the other as a comparison lamp and connected rigidly to the photometer head, a balance was obtained without the disk and then with the disk on the side of the standard lamp. The distances of the photometer from the standard lamp were well over those necessary to avoid errors

from the inverse-square law.

The two sets of 150° openings were then intercompared with each other and their value computed from that of their sum. A similar test gave the value of each pair of openings giving 100° and of each set giving 200°. The 180° disk was then compared with both pairs of 150° out of the 300° disk and with the three groupings which gave 200°. It was measured also by the two-lamp method and also against the 180° disk of the Bureau of Standards kindly loaned by that institution for the purpose. The three methods gave results which checked to within one-tenth of one per cent. A similar procedure was followed in stepping down from the 180° disk to the 90°, and the 30°. In the latter two cases a 32-cp. carbon lamp replaced the previous 16-cp. standard.

The 12° disk was measured in terms of the 15° and 10° of the 30° disk, and the 6° disk was then determined from the halves of the 12°. At this point a new 6° disk was made and sent to the Bureau of Standards to be calibrated for angular opening of the open sectors at different distances from the center of the disk. Values were given by the Bureau at six points, 2 cm. apart, starting 1.5 cm. from the periphery and representing the average of two measurements of four settings each at each point or a total of 288 settings. It was found that for the part of the openings actually used in the photometric calibration (about 1.6 cm. out of a total opening of 11 cm.) the resultant transmission given by the Bureau agreed with that determined by the step-down method to within one-tenth of one per cent. While as has been noted, the "cascade" method involves the possibility of having the experimental errors add up, it was felt that this check at the low transmission point reduced to a very large extent the probability of cumulative error. Furthermore, the duplicate disks available made considerable intercomparison possible. Thus, the two 90° disks were measured in terms of each other, of the two pairs of 90° from each of the 180° disks and of the three groups of 90° from the 270° disk, etc.

As noted in the introduction, the work of Hyde carried the verification of Talbot's law down to an opening of 10°. A further extension to 2° seems very highly probable as the result of a series of determinations of the value of the 2° disk in terms of the 12° disk. The 12° disk was placed and rotated between the

photometer and a high-candlepower standard lamp. The distance of the other lamp was then adjusted until the photometric balance came at a convenient point on the bar and the usual settings were made. The 12° disk was then replaced by the 2° disk and a 60° disk was placed and rotated between the photometer and the comparison lamp. This, of course, reduced the illumination on both sides of the photometer-head disk, but the photometric settings came at about the same point on the bar. The value of the 2° disk was thus determined from the value of the 12° and the 60°. The result agreed with that obtained by the step-down method to within a few tenths of a per cent. While this test is not rigorous, since it involves assumptions regarding the effect on the eye when viewing two surfaces, each illuminated by a light flux interrupted, but at such a frequency as to eliminate objectionable flicker, and also a difference in the illumination of the photometer-head disk, it seems highly improbable that an error in Talbot's law could be exactly compensated by possible errors resulting from these sources.

In making measurements on these low transmission disks, great difficulty was experienced in getting a light source of sufficient intensity and at the same time sufficient constancy, to permit of enough distance between the photometer and the standard lamp to avoid errors due to the inverse-square law, and still give sufficient illumination on the photometer-head screen to make accurate readings possible. This difficulty was finally overcome by the construction of a special gas-filled tungsten filament lamp made with four loops all hanging in one plane, and having welded terminals. The lamp takes 20 amperes at about 80 volts and has enough intensity to give a good illumination when using a 2° disk, with the photometer at a distance of 100 cm. from the lamp.

Mr. Taylor of these laboratories has called the attention of the writer to still another method of calibration which may be used with any two disks the transmissions of which are not exactly the same. It consists in a determination of the relative values either by the ordinary method of substitution or by putting one disk on one side of the photometer head, the other on the other side, making a setting and then reversing the disks. After getting the relative values the two disks are placed together so that the closed and open sectors overlap and the resultant transmission is

measured as if it were that of a single disk. From the two sets of measurements, one giving the ratio and the other the difference, the individual transmissions can be computed.

A word might be said regarding the speed of rotation necessary to avoid errors due to flicker. It has generally been the custom to rotate disks at a speed such that no objectionable flicker is seen in the photometric field. The flicker is a function of the number of times per second the light beam is interrupted. Since for a six-opening disk the beam is intercepted six times in one revolution and for a one-opening disk once, the speed of the latter must be six times that of the former to produce the same number of alternations per second. Recent experiments have shown that for disks with transmissions greater than about 25 per cent. no appreciable error due to flicker will occur if the disk is run at such a speed that the number of alternations per second is greater than 30. For disks with smaller transmissions higher speeds are necessary. It has also been shown by experiment that if two disks, having the same total transmissions are rotated at such speeds that the number of alternations per second is the same, the number of the open and closed portions is immaterial if they are symmetrically distributed. On the other hand, comparing disks with different total transmissions, the relative sizes of the open and closed parts make a difference in the case of disks with transmissions lower than 25 per cent. This is the reason why a disk with a transmission of 1 or 2 per cent. must be rotated considerably faster than one of 20 per cent., when the number of openings and their distribution is the same.

It may be added that the exact speed of rotation at which flicker disappears seems to be quite difficult to determine, but in the above experiments it was found that no difficulty was experienced in making photometric settings if the flicker was small enough, even though not entirely absent.

DISCUSSION

The paper by Mr. F. E. Cady was discussed through correspondence.

P. G. NUTTING: All workers in precise photometry will welcome Mr. Cady's review of the work on Talbot's law and of recent sector disk research at Nela Park. Of particular interest to me are the methods of calibration used and the limits of application of Talbot's law.

I should like to ask Mr. Cady whether the use of one of the sensitive modern forms of photoelectric cell, in differential arrangement might not serve better than the eye in disk calibration by eliminating the visual effect. Each of the methods used by Mr. Cady appears to give the combined error of the disk and of the eye, two quite independent quantities.

The Reciprocity law, $E = It$, in photography breaks down at about 0.01 mc., or roughly 0.005 erg sec. / cm^2. The corresponding law for the human retina probably has a limit of the same order of magnitude. For photoelectric sensitive surfaces, the limit of the corresponding reciprocity law is probably somewhat lower. It is to be hoped that all three limits may be determined by competent investigators in the near future. After determining these limits, the next points of interest will be the effect of frequency and of varying ratio of exposure to rest period.

S. L. E. Rose: With the great range in candle-power of modern light sources the sector disk is a necessary adjunct in their photometry. It increases the range of the ordinary photometer with a minimum of labor and time and the photometrist feels confident that any source of error in their use is practically negligible. The paper by Mr. Cady is one of the best which has come to the writer's attention and it is very gratifying to know that Talbot's law probably holds down to disks of two degrees. Mr. Cady very clearly gives the sources of error to be guarded against in the construction, painting and use of the sector disk.

At the Illuminating Engineering Laboratory our spectrophotometer is equipped with a Hyde variable sector disk and our other photometers have sector disks with fixed openings. These disks are mounted on separate stands, in no way attached to the photometer, so that no vibration is transmitted to the photometer head, and enables them to be readily used on either side of the sight box. The motor driving these disks is controlled by a rheostat so that the speed may be varied to suit the size opening being used.

Enoch Karrer: Mr. Cady has mentioned the fact that symmetry in the open and closed sectors is essential. This is of some importance, and has I believe been the cause of some apparently contradictory observations on the sector disk law, that have come to my attention. It is, however, not merely the

mechanical symmetry of the stationary disk, but temporal as well as mechanical symmetry when the disk is rotating. For, in order that the various opaque sectors of the disk should deplete a beam of light to the same extent, they must not only be equal in area, but they must eclipse the beam of light for the same length of time. The two factors, area and time, are coequal. In a symmetrical disk this effect would tend to be eliminated even when there is marked eccentricity caused by the driving mechanism, because then there will be periods of acceleration as well as periods of retardation for either the eclipsing or open sectors. There is little doubt but that the sector disk law holds for an indefinite range and for all colors. It has been assumed to hold for disks having a total open area of a fractional part of one per cent—considerably less than the lower limit mentioned by Mr. Cady.

As to the question of the validity for different colors I have recently had occasion to make this experiment. A Martens photometer was directed toward a tungsten lamp (250 watt, type C). A sector disk was allowed to intercept the illumination on one portion of the photometric field and kept uniformly bright by turning one of the prisms as is usual with this instrument. Now it was observed that the two portions of the field always remained color matched, for all sectored disks, of whatever kind, that were introduced. Since the variations in intensity were of no concern for the experiment, any method of eclipsing without flicker could be used. So that it was easy to make sectored disks for the purpose of any desired proportions. Such color matching can be done with great sensibility, so that it may be concluded therefore that the sector disk relations as shown by Hyde to hold for white and colored lights must hold for all colors, for all openings and over a large range of periodicity.

There is one more point in regard to a variable sectored disk, which may be somewhat out of order inasmuch as Mr. Cady has not given any space to the sectored disks of the second class. Two noteworthy illustrations of them are those of Lummer and Brodhun and that of Hyde. I have recently had occasion to try a sectored disk that decidedly differs from these. In all the above cases the sectored disk is essentially a thin plate. If we bend the eclipsing sectors of an ordinary disk at right angles to the plate, we obtain a cone or cylinder that may still be used as a sectored

disk. It is readily seen that if we eliminate half of the sectors and properly design the remainder, we obtain an eclipsing cylinder, whose depletion factor can be calculated, and which can quite easily be made to vary while in operation. It can be made more universal and not restricted for use with a narrow slit as in the Hyde disk.

L. C. PORTER: I have read the paper with interest, and find there is little I can add to it, although one point is perhaps worth while bringing out.

In the last paragraph of the paper, the statement is made that the exact speed of rotation at which flicker disappears seems to be quite difficult to determine.

There are other factors than speed entering into the question of flicker. A considerable study of this has been made in connection with shutters used on motion picture machines, and it has been found that apparent flicker on the screen depends to a great extent, upon the intensity of illumination, as well as upon the speed. Maintaining constant speed and decreasing the intensity of light on the screen will, apparently, cause flicker to disappear.

It is probable that the same results occur in connection with the use of flicker photometers.

A. H. TAYLOR: Mr. Cady refers to the use of a series of four disks having transmissions of 50, 60, 70 and 80 per cent when used singly, and which can be superposed in pairs to give transmissions of 10, 20, 30 and 40 per cent. The addition of a fifth disk having a transmission of 55 per cent would give a series of five disks from which transmissions of 5, 10, 15, 20, 25, 30, 35, 40, 50, 55, 60, 70 and 80 per cent could be obtained in the manner described. Hence a series of five separate disks would give practically all transmission factors required in most photometric laboratories. There is no reason why phosphor bronze edge strips could not be used on these disks, in fact it is very desirable that they should be.

With regard to the method of standardization of disks which I pointed out to Mr. Cady, and to which he refers in the latter part of his paper, this method has a more important usefulness than that which he describes. By measuring the transmission of two disks combined, *e. g.*, a 50 and a 55 per cent disk, and then determining their relative transmissions by operating one on each

side of the photometer and then reversing them, a high precision determination of the transmission factor of each is obtained. Either of these disks may then be combined with a disk of unknown value, and the unknown disk determined with higher precision than a direct measurement of that disk alone.

The "reversal" method of intercomparing disks which are nearly alike in transmission gives results of double the precision obtainable by the substitution method, since the ratio of transmissions is the same as the ratio of the first power of the photometric distances, rather than the squares of these distances.

The following method of standardization of low transmission disks is very useful: If a standardized disk having a transmission factor which is approximately the square root of the factor of the unknown disk is used first on the test lamp side, then on the comparison lamp side, the unknown disk being placed on the test lamp side in the latter measurement, a value for the unknown disk may be computed from the observations. The principal disadvantage in this method lies in the fact that the second power of the transmission of the known disk enters into the calculations, which may cause an error unless its factor is accurately known.

C. E. FERREE: During the winter and spring of 1903-04 I made an investigation of the Talbot-Plateau law under the direction of Dr. E. L. Nichols of Cornell University. Two similar seasoned lamps were compared photometrically, one run at low voltage giving a reddish orange light, the other at high voltage giving a bluish light. The comparison of the two lights was made by the law of squares, and by the sectored disc for a wide range of open sector. A number of observers were used in making the judgments. The correction factor needed to give exact agreement between the two methods was small and apparently not significantly greater for the low values of open sector than for high values. However the two lights employed did not differ greatly in composition nor were the tests extended to cover a wiide range of composition of light. From the work that has been done thus far I do not believe that we can feel entirely satisfied that the law holds for all values of open sector for all compositions and intensities of light.

The Talbot-Plateau law may be stated as follows. The effect of light on sensation is the same whether acting continuously or

intermittently provided that the intermittence has reached the fusion rate and that the eye receives in both ways the same amount of light in a unit of time; and there is no change in the effect however much the rate of intermittence is increased. If the law is not valid for all compositions of light, in other words if the sectored disk when used in connection with the eye acts like a selective filter, photometric calibration is the only course open and separate calibrations would be needed for different lights. If on the other hand the law is valid for all values of open sector for all compositions of light, I can see no great advantage in the photometric calibrations unless it shows greater sensitivity and precision than is feasible to attain by a direct measurement of the disk. However, inasmuch as it requires nothing to be assumed as to the validity of the Talbot-Plateau law, which in my opinion has been none too widely tested, the photometric calibration appeals to me. Further, it must be remembered, that if the rotation of the sectored disk does not reach the fusion rate, in other words if flicker is still present the use of the sectored disk does not even fall within the conditions laid down as necessary by Talbot and Plateau and by others who have studied the action of the eye under intermittent stimulation.

In 1916 ("A Spectroscopic Apparatus for the Investigation of the Color Sensitivity of the Retina, Central and Peripherial, *Jour. of Exper. Phychol.*, I, pp. 247-284) we described a set of sectored disks which have proved very serviceable for photometric and other laboratory purposes.

The best motor we have been able to find for the rotation of sectored disks and for similar laboratory purposes is light and compact and is suspended by three coiled springs to take up vibration. Its speed ranges from 200-6000 r. p. m. By means of a rheostat which we have constructed specially for this motor very fine changes of speed may be made which are fairly reproducible when the motor is operated on a storage battery. This combination of motor and resistance serves a very valuable purpose in the study and practice of flicker photometry where small changes of speed are needed and in the study and demonstration of all the phenomena produced by the intermittent stimulation of the retina.

B. E. SHACKELFORD: The paper is an excellent resumé of the use and calibration of sectors disks and will be of advantage to

the various laboratories because of the fact that it brings together in condensed form the available information.

Whenever possible, we make use of the method of substitution rather than that of special calibration of our disks.

F. E. Cady (in reply): In answer to Dr. Nutting's question, it may be said that while the use of the photoelectric cell would eliminate the eye error during calibration, this error would be present in the use of the disk with an ordinary photometer and, hence, would have to be taken into account. The methods described in the paper were worked out with the idea of calibrating the disks as nearly as possible under the conditions of their normal use with the regular types of photometer. Furthermore, while some work has been done on the verification of Talbot's law in connection with disks used with photoelectric cells,[1] a more complete verification would seem to be desirable before assuming this law for purposes of calibration.

In spite of the evidence presented in this and previous papers, Dr. Ferree seems doubtful of the validity of Talbot's law "for all values of open sector for all compositions and intensities of light." It is true that the proof so far has been limited to openings as small as 2°, and to a few measurements with different colored sources, but these limits would seem to be ample to cover the necessities of all ordinary photometric work, and this is the type of work for which the paper was written.

(1) Kunz, *Astrophys. Jour.*, 45, p. 69, 1917.

THE POLARIZATION METHOD OF MEASURING THE GLOSS OF PAPER AND SIMILAR SURFACES*

BY L. R. INGERSOLL**

The matter of glare from highly finished book and magazine papers is one which has of late attracted a great deal of well merited attention. It is probable that almost every one can recall an experience—similar to the writer's—in which he has at some time or other suffered so much eye strain from reading certain periodicals printed on glossy paper that he has been decidedly prejudiced against such magazines.

It may be remarked that printers as a whole are quite alive to this situation—which is well set forth in a little pamphlet written by the Committee on Glare from Reflecting Surfaces of the Illuminating Engineering Society—and a determined effort is being made to secure paper of a moderate finish which will still allow the production of fine half-tones, but some years ago the writer came to the conclusion that any real progress in mitigating this nuisance of glare from glossy printing papers will require some more or less exact way of specifying the gloss or degree of finish of the paper used. The result of a study of this subject has been the development of the polarization method and instrument for the measurement of this quality of gloss, and it is this which is about to be described.

It will be recalled that there are two types of reflection which light may suffer at a surface. The first of these is called "specular" in that it is exemplified by the mirror. In this case the angles of incidence and reflection are equal and the other laws of regular reflection obeyed. The size of the image of the source as seen in a mirror is dependent on the distance the source is away but its intrinsic brilliancy is independent of such distance. The other type is "diffuse" reflection. In this case, there is no regularity of reflection, no obedience to the law just cited of equality of angles.

Now in most surfaces, of which paper is a very good example, there occurs a combination of these two types of reflection.

*A paper presented before the Philadelphia Section of the Illuminating Engineering Society, March 18, 1921.

** Physical Laboratory, University of Wisconsin.

Such a surface might be thought of as produced by overlaying a perfect matte surface with one or more sheets of glass. Perhaps, a better way is to regard it as a combination of little specularly-reflecting facets, produced by the calendering process, between which are diffusely-reflecting areas. The specularly reflected light from such paper constitutes the glare which we have been discussing, while the diffuse reflection gives rise to the soft general illumination. The above discussion of these types of reflection shows furthermore why the glare is so much more annoying when reading at night, especially at some distance from the source of illumination, for the brilliancy of the source as seen reflected from the paper is independent of its distance, as remarked above. The glare then will be decidedly dependent upon the type of illumination, but if we adopt a standard type for purposes of measurement as will be described later, the gloss of a surface may be defined in terms of the glare to which it gives rise.

Now there are at least two different ways of measuring and specifying gloss in terms of specular and diffuse reflection; the first has already been described before The Illuminating Engineering Society by Dr. Nutting.[1] While an essentially direct and accurate method, it requires expensive instruments and is somewhat more complicated than the polarization method now to be described. In discussing this method, perhaps, a word or two in regard to the principles of elementary physics involved will not be out of place. The illuminating engineer, while an authority on the subject of light and lighting, is not as much concerned as is the physicist over what light really is. As a result of investigations of the last two hundred years or more, the physicist knows that what we term "light" is a wave disturbance, electromagnetic in character, belonging to the same family as the X-rays which are some ten thousand times shorter, and the wireless waves which may be a million times longer than ordinary visible light waves. These visible light waves are indeed very short, being in ordinary units only 1/2000 of a millimeter or the fifty-thousandth of an inch in length for light of a blue-green color.

Ordinary light is unpolarized, that is to say, the vibrations take place in every possible orientation at right angles to the direction of propagation or ray. By certain means, however, we

[1] TRANSACTIONS. I. E. S., Vol. VII, p. 412.

can plane-polarize light, that is, suppress or cut out all vibrations except those which take place in a single plane. More accurately we take only the components of vibration which lie in this one plane. The time-honored example of the clothes line which is being vibrated in every possible direction and which is allowed to pass through the back of a chair with vertical rods is a good one here. It is obvious that only vertical vibrations can proceed down the rest of the line.

There are two simple ways of polarizing light. In the first it is allowed to go through a piece of double-refracting material cut or worked in a certain fashion. The commonest example of such is the nicol prism which transmits only such vibrations as are parallel to the shortest diagonal of the nicol prism. The other method is by reflection at the surface of a dielectric or non-conducting material such as glass, or even water. When this reflection takes place at a certain oblique angle termed the polarizing angle—determined by the fact that the tangent of this angle is the index of refraction of the substance—almost complete polarization takes place. That is, the specularly reflected light is all plane polarized and in such a way that the vibrations are parallel to the surface. Such polarization would be recognized, not by the eye, for the unaided eye cannot recognize polarized light, but by examining the reflected light with a nicol prism. It is found that when the shortest diagonal of the nicol is horizontal the light gets through and when it is vertical none of this light is transmitted.

Now if we examine a surface of glossy paper under these same circumstances we find that the specularly reflected part of the light—that is, the glare—is almost completely plane polarized just as was the case with the glass plate. The diffusely reflected part, however, is unpolarized. When the writer first noticed this it occurred to him at once that the glare might well be measured by the percentage of polarization in the obliquely reflected light. More accurately, if one is to examine a sheet of paper in such a way that light from a source subtending a certain angular magnitude is directly reflected at an angle of about 57 degrees into the eye, then the fraction of the brightness of the sheet which is due to polarized light may be regarded as a measure of the glare (in certain arbitrary units) and is taken as a measure of its gloss.

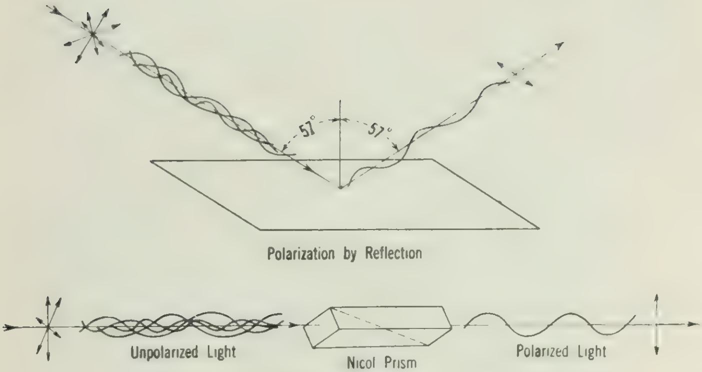

Fig. 1—Polarization Methods.

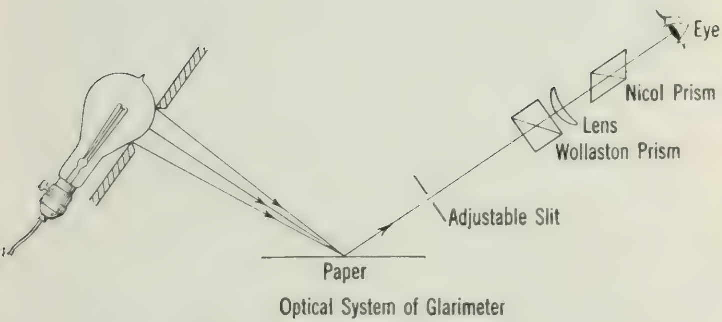

Fig. 2—Optical system, incident and reflected rays at 57° with normal to plane of the paper.

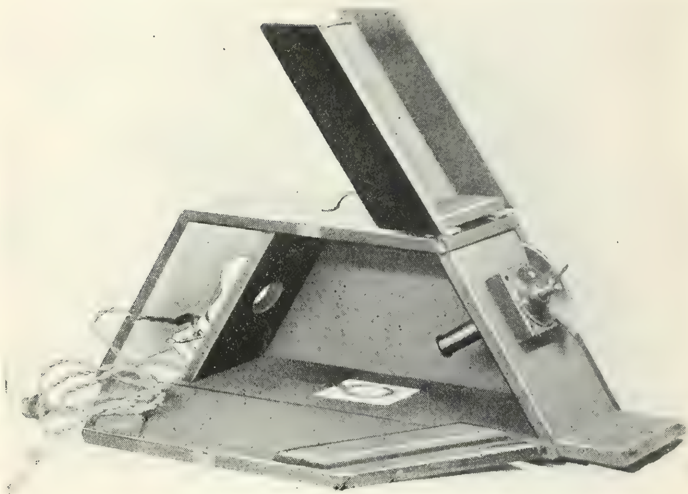

Fig. 3—The Glarimeter.

This in brief is the principle of the polarization method of gloss measurement.

There are several possible ways in which it may be embodied in instrumental form. The one which is described and illustrated here is particularly designed for use in paper mills. The operation of the instrument will be made clear by a study of the Figs. 1 to 3. The first illustrates the polarizing action of a nicol prism and also polarization by a glass plate or sheet of glossy paper. Now, of course, we could form some estimate of gloss by simply turning a nicol prism about the axis of the reflected beam and making a mental estimate of the magnitude of the change in brilliancy as it is revolved. Such a scheme would not be at all suited to exact measurements, however. For these we must make use of the principle of the bi-field. It is a well-known fact that while the eye cannot judge absolute brightness with accuracy it is very successful in determining relative brightness, or rather in matching two halves of a field so that they are of the same brightness. This can, as you well know, be done with an accuracy better than a half of one per cent and is indeed the principle of practical photometry.

The exact way in which this bi-field principle is applied, as well as other details of how the method is worked out is made clear in the second figure. It may be remarked that the optical system is of considerable improvement over the early and somewhat crude form described elsewhere.[2] The source of light is a white-glass 50-watt tungsten lamp placed behind a diaphragm which subtends at the paper a definite solid angle, which has been fixed after some experimentation at about 0.03. The light is incident at an angle of 57 degrees, measured from the vertical, and the paper sample is held in a special clip.

The light then enters the polarimeter which is a modification of an instrument known to meteorological observers in connection with sky polarization measurements as the Pickering polarimeter. In the form as modified it consists of a slit, which is adjustable in width, a quartz Wollaston double-image prism, a simple lens and a nicol rotating in a divided circle. On looking in the eyepiece—supposing for the moment that the nicol has been removed—we see two images of the slit formed by the

[2] Electrical World, March 21, 1914.

double-image prism. They are of two mutually perpendicular planes of polarization, that is, the upper slit image is polarized with electric vector horizontal, say, so that it contains all the specularly reflected component as well as half the diffuse. The other slit cuts out the glare and lets through half the diffuse. The two will obviously then be of very unequal brightness, but if viewed through a nicol and the latter turned through the proper angle, they may be brought to the same brightness. When this is the case, simple mathematical considerations show that the fraction of the light which is polarized is determined by the simple process of taking the cosine of a double angle. It is now recommended, however, that the gloss be expressed directly in terms of the angle as read on the scale. While this may seem at first very arbitrary there are a great many things to be said in its favor. On this scale, a soft blotting-paper surface will read about 20 degrees of gloss, a dull finished piece of print paper 25, a low gloss 30, medium gloss 35 and high finish 40. The very highest finish in white paper—glazed surface—reads 50 degrees.

The third figure shows how these principles are embodied in a practical instrument which the writer has termed the "Glarimeter" inasmuch as it measures gloss in terms of glare. There are a number of possible fields of usefulness for this instrument. Undoubtedly the most important one is in the paper mill where its use will enable the manufacturer to control the uniformity of finish of his product just as he now does its basis weight, strength and other qualities. A number of paper mills are already using these instruments and give very favorable reports of them based on the speed and accuracy with which determinations may be made even by inexperienced men.

Another field of usefulness lies in the assistance it will render the paper user in specifying exactly the degree of finish he desires. This point may not, at first sight, appeal so favorably to the paper maker, but when it is remembered that the same instrument which enables the user to specify will also assist the maker in complying—within reasonable limits, of course—with these specifications, that it will eliminate guess work and the possibility of a misunderstanding over what constitutes a "high finish" or "medium finish," it is probable that the maker will welcome its advent into this field, as well as the user.

Certain other uses may also be suggested :—It will prove useful in testing and grading photographic stock, it can be used to give point to legislation already suggested to limit the allowable gloss in school book papers, it may help the printer in his choice of inks for certain purposes, and it will assist in the development of improved book or magazine papers.

The last point will bear explanation. There are really two distinct qualities concerned when we speak of the gloss or finish of paper, one being its mechanical smoothness or "feel," the other its "optical smoothness" or glare-producing quality. In general the two are proportional, particularly in a given type of finish where the glarimeter which measures primarily only the latter quality serves with equal accuracy to determine the former. When widely different sorts of paper are concerned, however, this may not be exactly the case. An exaggerated example would be a sheet of super-calendered paper in which one had pricked many fine needle holes. Such a sheet would still give a high gloss reading but would feel, on the burr side at least, decidedly rough.

Now the printer, having in mind his fine half-tones, desires a smooth paper, but because of the awakening public interest in the matter of eye discomfort from glare, must not use too highly finished stock. The development of a paper with smooth surface but low glare-producing quality is accordingly highly to be desired. Some decided progress has already been made along this line but more is sure to follow, in which, it is hoped, the glarimeter will have a part.

While it is intended primarily for white or lightly tinted papers, the instrument can be used satisfactorily with colored stock when a piece of glass of approximately the same color is inserted in the eyepiece. Its use, however, is not limited to papers for in a somewhat different form it might be used to measure the gloss or finish of a desk top, wall, automobile body, textiles, etc. The method has just one essential limitation and that is it is not applicable to surfaces showing metallic reflection. Such surfaces do not polarize in the way already described, and accordingly cannot be tested in this fashion. There are not so many practical cases of bright metal surfaces which it would be desirable to test in this way, however; most such surfaces are painted—as auto bodies—and they are readily tested.

Reverting, in conclusion, to the idea developed at the outset of the evils of glossy book or magazine paper and the desirability of remedying them, the writer would like to make some specific suggestions as to what the Illuminating Engineering Society can do to improve conditions in this respect. It is believed for instance, that a recommendation that children's school books be printed on paper with a gloss of less than 27 or 28 degrees, would be a move in the right direction. A recommendation of this character indeed was adopted some years ago by a New York Association of school principals, but as there was no means of measuring gloss, the specification could be made in only the most general terms. In the matter of ordinary reading matter for adults a little higher finish is allowable, perhaps. There is reason to believe, however, that there is a rather narrow limit of gloss—about 30 degrees on the scale of the glarimeter—which will still yield sufficiently good half-tones and at the same time be relatively easy on the eye. A little lower finish than this and there is trouble with the illustrations; a little higher and the eye begins to feel the strain from the glare. A number of magazines are now standardizing on paper of about this gloss and it is believed that the pressure of the opinion of this Society, representing as it does the crystallization of a more or less hazy but powerful public demand, could eventually bring about its general adoption.

MAKING NATURAL COLOR MOTION PICTURE FILMS*

BY WM. V. D. KELLEY **

To many persons not actively engaged in some branch of the motion picture business who are usually only casual visitors to the cinema theatres, a colored film may mean one using one or more of the following methods:

(a) tinting
(b) toning
(c) hand coloring
(d) stencils
(e) impressions from matrixes

all of which make use of the ordinary black to white film and are colored by means within the scope or taste of the individuals doing the work.

Generally the results are in the nature of mass effects, although the stencil and printing systems do select and color portions of the scenes—usually the still portions—quite accurately. In the Pathe stencil process the costumes and very fine details are often remarkably well done.

Consider that the total area of the scene on the films is less than 0.75 in. by 1 in., that the magnification is more than 200 diameters, that there are 16 complete pictures showing each second and 16,000 pictures in a single reel, that the slightest variation in tint, or shade, or wandering, of the color, is visible to the audience and one will begin to realize some of the difficulties encountered in coloring lengths of films.

NATURAL COLOR PICTURES

The process that is the subject of this paper differs from all of the above in that the work is mechanical, chemical and optical. The choice of the colors and the final results depending on the accuracy of the plans.

In the words of Professor Louis Derr of Mass. Institute of Technology:

* A paper presented before the New York and Philadelphia Sections of the Illuminating Engineering Society. February 10 and 18, 1921.

** Prizma, Inc., New York City.

"1. The process is well founded and carefully built upon a sound scientific basis, and is scientifically up to date.

"2. Some colors are excellently produced, but not all in a given area. By the use of special filters in the taking camera, particularly subjects of limited color range can be almost perfectly reproduced. The process should be of particular value in scientific films, advertising films and films involving portraits. The 'feature film' which does not demand violet and bizarre lighting effects also seems to me to offer a particularly inviting field.

"3. The product can be used in the ordinary motion picture projector, without change or modification of any kind in the mechanism and requires no special skill on the part of the operator.

"4. The process is mechanically simple, and presents no difficulty in the way of quantity production."

In other words, we do fairly accurately what every user of a camera has desired, namely to take the pictures in the negative so as to reproduce on the positive the scenic view or object as one sees it on the ground glass or view finder—that is in the colors of nature.

Scientists do not agree as to the actual means by which colors are produced or as to why we see them as we do. We do know that as a practical proposition white light may be divided into three parts—red, green and blue and that with these three colors plus white or black, one can reproduce all shades or mixtures of colors.

We also know—practically—that with a complimentary pair of colors—for example a red-orange and the complimentary color of green-blue that mixtures of these two colors will give all of the colors found prepondering in nature—the weakness appearing in yellows which show as orange yellow and purples which show as browns. But here, even, the inaccuracy is not noticeable if the colors taken in association are suitable.

The above statement merely means that any one pair of colors will not reproduce every color in any one picture area. However, in making motion pictures one is not confined to any one pair of colors throughout the reel and by using filters to suit the scene or objects being photographed, he can in a reel or film show every color and shade that the eyes will perceive.

To reproduce every shade and color in any one picture area would mean dividing the spectrum into three parts. In motion-picture photography, due to the facts outlined in the above paragraph and also due to practical considerations, we have found that by dividing the spectrum into two parts, we are able to produce satisfactorily all that is required for our work.

TAKING THE PICTURES

In such a two-color process the pictures are taken in pairs on a single width film, one over the other, or on double width film, the images being side by side, one picture being taken through a red-orange filter and the companion picture through a blue-green one.

The negatives are developed in total darkness, or by means of a safe light which is green and not red. Otherwise, they are handled exactly as ordinary films, being passed first through a developing bath, then through a fixing bath and finally given a wash.

After being dried the negative is used for printing on to the positive. The positive may have a single coating of the sensitive silver emulsion on one side or two coatings, one on each side. The negative generally used in our work is of the single strip variety with the adjacent images in pairs, one over the other, so that throughout the length of the negative the red picture alternates with the green value picture. The pictures at this stage are in black to gray silver and without color, the color being represented in the values of the amount of silver deposited. The printing machine first prints all of the red value pictures in close succession on the positive, this being done by a device that feeds the negative pictures two areas and the positive one area. The second set of pictures, representing the green-blue ones are next printed exactly over the red pictures. This work is kept accurate to a very high degree so that the pictures in projection show no offset within the limits of the defining power of the projection lenses. This is a point of very great practical importance, for inaccurate registration of the pictures, which would have a persistent fringe of color, would not only mar the picture but would probably cause eye discomfort to the spectators.

DEVELOPING THE FILMS

The positive film is then developed, fixed and washed, after which it is passed through a bath which bleaches or oxidizes the silver so that the film apparently contains no image.. The film is then dried. This clearing process is a very necessary step in the conversion of the black opaque silver image into a transparent dye image, the technical term of which is dye-toning. During the treatment in the oxidizing bath, the gelatine acquires a curious and valuable property of absorbing certain kinds of dye in proportion to the amount of silver in the image and of holding the dye so that it is not washed out by the subsequent immerging of the film in water for clearing the film of any stains. The particular process used produces unusually clear whites, a valuable function in this kind of work.

COLORING THE FILMS

This is performed in a special machine after the film has been dried. The film passes over baths containing dye, and the entire surface of the gelatine is permitted to touch the dye bath, but due to the previous treatment the dye is absorbed only where the silver previously occupied the gelatine. In this same machine the film is dried and as it emerges is ready for titling and joining into full reels. It does not stop anywhere in its course through the machine and may be examined by daylight at any point in its journey.

RESULTS

Color is physiological and depends on the human element, or the state of one's eyes, or it may be altered by his physical condition. All of us are color blind to some extent, the degree depending on our training. For the same reason, the lower races of man, not appreciating tints and delicate mixtures, select the most gaudy colors for adornment. The same statements hold good in the public showing of our films. The newspaper critics get into print and we learn to know what they like. Others do not get such publicity, but we learn what they think by one means or another. It is surprising. I could give dozens of examples, but just two of wide variety will do. The writer of technical

articles and a student of color photography on one of our trade papers says: "We favor bright, vivid colors." While another writer on the N. Y. *Times* says: "And only last week the Prizma Company revealed its best work of the year, a screen version of "Heida" in colors, which had a chromatic quality far superior to the same company's earlier attempt with Whittier's "In School Days," referring to a three reel designed to carry soft pastel shades with no vivid coloring whatever, while the picture "In School Days" was vivid with color.

Therefore, if the particular picture that you are witnessing jars you in any way, remember your neighbor sees it with another pair of eyes and most likely, differently.

If the pictures of the future are to be in color, I hope you will endeavor to standardize the curtain and the source of light—both of which should be kept as nearly as you can to a creamy white, the main variants in this country being the carbons used in the projector which gives tones from yellow to blue and the curtains which show about the same range. These changes act as a tint over the entire film and may make the picture appear either warm or cold.

A FOCUS-INDICATOR FOR HEADLIGHTS.

BY L. O. GRONDAHL*

The advances of the last few years in the design of headlight lenses and the progress made in the writing of headlighting specifications have resulted in greatly improved road illumination and in a considerable reduction in glare. The practical result, however, is still far from satisfactory. Anyone who has had to stop at the roadside at night in order to let "non-glare" headlights pass because it was impossible for him to see what he was driving into, realizes that the problem is not yet solved.

A number of headlight lenses are in use which, when properly adjusted, give good road illumination, good side illumination, and at the same time keep the glare below a value that has been considered allowable by the I. E. S. Committee on Motor Vehicle Lighting. The cause of the glare conditions that persist in spite of the use of good lenses is the difficulty in adjusting and maintaining adjustment of the headlight. In order to give the headlight lens an opportunity to function properly the lamp must be properly focussed and properly aimed. This ordinarily involves a careful adjustment of both these variables before the lens is applied to the lamp. It also means frequent inspection and readjustment for which it is necessary to remove the lens in each case.

It has been thought that vigilance on the part of the police would result in every driver making these adjustments as needed. The difficulty arises, however, that the officer in order to determine whether the device is or is not functioning in accordance with law must do one of two things: Either he must make photometric measurements in different parts of the beam (and that involves taking an instrument and having the car driven to a secluded spot), or he must take the car where he can project the beam on a wall and take off the lenses before he can see whether the lamps are properly focused and directed. The result is that it is too much trouble for the driver to keep his lamps in adjustment and it is too inconvenient and time consuming for the officer to determine whether the law is being obeyed. The lamps

* Union Switch and Signal Co., Swissvale, Pa.

get out of adjustment and remain that way, and in spite of the fact that automobile owners are buying and using really valuable devices we still suffer with the glare.

The importance of proper adjustment has been very strongly brought out by various writers and especially in the reports of the I. E. S. Committee on Headlighting Specifications. One difficulty often emphasized is the fact that it is not easy to write the directions for focussing a lamp so that the average driver can understand and apply them. The remedy seems to the writer to lie in increased convenience and simplicity in the method of making the inspection and the adjustment of the lamp. The first requisite is that the adjustment may be inspected without the removal of the lens, which is necessary at present. Such convenient inspection can be made in a very simple way, which can be applied to lenses that are designed with this end in view.

A lens to be used with this method of inspection and focusing must have one or more areas designed for use as focusing areas. When the inspection is to be made, a screen is placed over the lens, which covers all but these areas. If the lamp is directed so that the beams projected through these areas fall on a distant screen, there will be a spot of light corresponding to each focusing area. When the lamp is in proper focus, these spots occupy known relative positions. It is, therefore, a matter of only an instant's observation to determine whether the head-lamp is, or is not, properly focused.

If, as is true in the case of some head-lamps, it is possible to change the position of the lamp with reference to the reflector, without removing the lens or otherwise dismantling the head-lamp, the adjustment of the focus may then be made very quickly and easily. It is only necessary to move the lamp in the reflector until the two projected spots are in the proper relative position. After this is accomplished, the direction of the beam may be adjusted until the spots strike the screen at the proper distance from the ground. The operation is then repeated with the other head-lamp.

The number, position, and size of the openings in the screen depend on the design of the lens with which it is to be used. The

writer has designed a lens with two slightly prismatic or plane areas at opposite ends of a horizontal diameter which are used together with a screen such as is described above for the purpose of indicating when the lamp is properly focussed and directed. A single portion of the lens that is not violently modified may be used, the rest of the lens being screened off. Proper focus is then indicated by the size of the projected spot or by its shape. The most convenient is probably two openings at opposite ends of a horizontal diameter. The spots can then be superposed, brought into contact or into any other relative position to indicate the proper focus. The relative position is different for different lenses and depends on the design of the lens. If two such spots on a lens are brilliantly colored, for instance one red and the other blue, the same thing may be accomplished under some circumstances without a screen over the lens.

Directions for applying the device and for making all adjustments may be printed on the screen. The instructions are different for each individual type of lens to which the screen is to be applied. The screen will also in many cases be different for the different types of lenses. The most important step in the application of the screen will be shown in prominent characters on the screen so that the driver and the inspector may both know at once what to look for.

The directions printed on the screen might in a hypothetical case read as follows:

1. With the car fully loaded point the beams to a wall or screen fifty or more feet distant on a horizontal stretch of ground.

2. Cover one head-lamp and place the screen over the other head-lamp. If two separate spots are projected on the wall the lamp is not in focus. *Adjust the lamp until the spots projected on the wall coincide.*

3. Adjust the tilt of the head-lamp until the center of the *combined spot strikes the wall one foot below the level of the lamps.*

4. Make the same adjustments with the other head-lamp.

Such directions are simple enough to enable anyone to adjust his own head-lamps and to enable an officer to make a quick and

satisfactory inspection to determine whether the lamps are properly adjusted.

If no wall or other convenient screen is available, it is possible to determine, on a screen set at a distance of only a foot from the lamp, whether or not the lamp is in focus. This can be done in broad daylight, as well as at night. An officer could carry such a screen and a collapsible stand which he could set up in front of a car. This would make it possible to stop a car at any place on the road and to determine exactly the condition of the focus of the head-lamps. The procedure would be somewhat as follows:

The officer would obtain from the driver of the car the focusing screen that belongs to the particular type of head-lamp in use. He would then adjust his own screen so that certain marks on it would be at the same distance from one another as the openings in the focusing screen. When the focusing screen is then applied to the lens and the officer's screen is set up at a distance of one foot away from the lens, the spots projected would fall either on, or very near, the marks on the officers screen, Their proper position is known, and, therefore, any deviation from this position would indicate an improper focus of the head-lamp. It would be a simple matter also for the officer to carry an adjustable focusing screen that could be applied to any head-lamp lens that is designed for use with such a screen. The whole operation of testing the focus of a pair of head-lamps would take a very few minutes.

The device may be used to best advantage with head-lamps of which the focus is adjustable without dismantling. The focusing and directing then becomes a very simple operation. However, even in cases where that can not be done it serves as a method by means of which the driver or the officer can tell in a minute whether a set of lamps is or is not in proper adjustment.

This method of focusing, as well as the above-mentioned lens, designed especially for use with the focus indicator, are subjects of pending patents.

DISCUSSION

The paper by L. O. Grondahl was discussed through corresspondence.

L. C. PORTER: Mr. Grondahl has pointed out clearly in his paper the situation in regard to the use of automobile head-lamps which, even with the best and simplest of focusing equipment, or means of determining whether or not the lamps are properly focused, will, undoubtedly, continue to exist; namely, either the inability of the motorist to properly focus his head-lamps, or the crude and often inaccessible means provided for adjustment.

Even with the simplest adjustments readily accessible, there are many factors, such as variations in individual bulbs, variations in reflectors, sockets, etc., which would continue to cause as to prevent any change in the relative positions of socket, reflector, etc., in service. This equipment must be backed up by trouble. The remedy is a head-lamp in which the various parts are made with great accuracy, and mechanically so constructed an incandescent lamp which is made with great accuracy as to the location of the filament with respect to the pins on the base; that is, in regard to light center length, axial alignment, etc.

It has been very difficult, practically impossible in quantity and at a commercial price, to construct such an incandescent lamp in the past. The bulb is made up of various parts of glass joined together in a molten state, and under these conditions, manufacturing tolerances of plus or minus $^3/_{32}$ in. in light center length, and $^5/_{64}$ in. in axial alignment, have been necessary.

Recently, however, ways and means have been found of very materially improving these conditions, and lamps are now being made with such a degree of accuracy that when they are used in a head-lamp made with corresponding accuracy, no focusing mechanism is necessary. When one lamp fails, the lamp replacing it will give almost identically the same distribution of light as the lamp which it has replaced. Such a combination of precision lamp and head-lamp is in use on the Wills car.

I believe that work along these lines will be the ultimate solution of the head-lamp troubles. With such equipment, a reflector can be designed, or a combination reflector and lens used, which will give any desired distribution of light, and with

this distribution properly laid out, scientifically illuminate the road, and at the same time limit the glare, the problem will be very largely solved.

J. A. HOEVELER: While I believe that a focus-indicator of the type described in this paper would be useful to the individual motorist in keeping his headlights properly adjusted, there seem to be difficulties in applying such an indicator as the means for enforcing headlight laws.

The enforcing officer must have available a focusing screen for every type of head-lamp device he may encounter or an adjustable one as suggested by Mr. Grondahl and it would be necessary for him to be familiar with the adjustment for all of the multitude of so-called lenses now in use. This it seems to me is not simplifying his tasks but rather complicating it.

Experience with the Wisconsin headlight law firmly convinces me that the only practical way of enforcing the headlight law is by the establishment of official testing stations. Moreover, such testing stations to be most successful should be extremely simple. The ideal station, I think, is the one in which a car may be driven and with one observation it is possible to ascertain whether or not the headlights comply with the minimum requirements of the law.

Such a test station has been established in the city of Milwaukee. A set of three guide rails are provided at one end of the building into which the cars to be tested can be backed. Three cars can be spotted at one time. One hundred feet in front of the cars a movable test board is located. It is suspended from a track and can be slid directly in front of the headlights of any of the three cars to be tested. The board is white and in its surface are located four three-inch circular translucent bulls-eyes. These bulls-eyes are illuminated by small lamps placed in chambers at the rear of the board. The positions of these bulls-eyes correspond to the following:

1. Sixty inches above the level surface on which the motor vehicles stand and directly in front.
2. Sixty inches above the level surface on which the motor vehicles stand and seven feet to the left of position 1.

3. Twenty-nine inches above the level surface on which the motor vehicles stand and directly in front.
4. Twenty-nine inches above the level surface on which the motor vehicles stand and seven feet to the right of position 3.

The brightness of these bulls-eyes is adjusted so as to equal the illumination which would be produced at these points by head-lamps delivering the following candle-power values in the direction of these points:

1. 2400 candle-power.
2. 800 candle-power.
3. 4800 candle-power.
4. 1200 candle-power.

These positions and these candle-power values correspond to the Wisconsin requirements and are essentially the same at the I. E. S. automobile headlight standards. To determine whether or not the head-lamps under test are in compliance with the law requires merely the operation of the engine of the car so that the head-lamps will deliver their full strength of light. If the bulls-eyes at position 3 and 4 appear dark relative to their background, this is proof that the head-lamps are supplying more than the minimum road illumination called for by the law. If the bulls-eyes corresponding to 1 and 2 remain bright relative to their background, this is proof that the brightness of the headlight in the upper regions does not exceed the maximum permitted by the law.

This test station is operated by two police officers; one officer is stationed at the guide rails and directs the placing of the vehicles, the operation of the engines, and the lighting of the head-lamps; the other officer is stationed at the test board and is in charge of placing it properly in front of the vehicle to be tested. It is also his duty to adjust the rheostat to keep constant the voltage of the test lamps on the board.

This very simple test station was designed and placed in operation by Mr. Howard F. Ilgner, Illuminating Engineer, Bureau of Illumination Service, City of Milwaukee. While the station is operated by the police department, Mr. Ilgner's department supervises the work and periodically checks up the standard lamps employed for the illumination of the test bulls-eyes.

P. W. Cobb: Mr. Grondahl's device, in its fundamentals, reminds me of a classical experiment, known as Scheiner's experiment by means of which the thoughtful medical student may gain familiarity with the manner of passage of light-rays within the human eye. It consists simply in looking with one eye at a small object through a pair of pinholes punched in a card and close enough together so that both may be included within the area of the pupil, thus permitting vision of the object through both pinholes at once. This card, then, is the analog of Mr. Grondahl's screen. If the eye is focused for the object looked at, the latter will be seen single; otherwise double, since in this case the two rays of light coming from the object will cross in front of, or behind, the retina. The parts of the visual refractive apparatus through which the two rays of light pass correspond to the test-areas of the lens in the case of the head-lamp.

If now, we were to imagine a small light-scource within the eye, which we wished to bring to a focus upon a certain screen without, the analogy is complete. The correct position of the lamp would be absolutely determined by the coincidence of the two images upon the screen.

The light traversing the remainder of the headlight lens is, of course, intentionally more or less broken up, as compared with the case of the eye; a certain distribution of light being desired rather than a geometric focusing of the filament-image The proposed method of testing is nevertheless correct. It will devolve upon the manufacturer to see that the test areas of the lens stand in the right relation to the design of the lens as a whole, so that when the test shows the lamp to be in the right position, the distribution of the light from the whole lens will meet the user's requirements.

G. N. Chamberlain: There is now on the market a variety of lenses, reflectors and other devices capable of giving satisfactory road illumination if properly adjusted, and any device which will assist the user to adjust and take care of his equipment so that the required effect can be obtained should be

gratefully received. Such a device is undoubtedly covered by Mr. Grondahl's paper.

The eventual solution may be looked for in precision of design and manufacture, a positioning of the complete unit and its integral parts so that no future adjustment is required or arranged for, even though the lamp has to be renewed. Such a device has come out on one of the newer cars this year and is apparently giving the desired results.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XVI | OCTOBER 10, 1921 | No. 7

REPORT OF THE COMMITTEE ON PROGRESS FOR 1921.*

INTRODUCTION.

"Long life to the moon for a dear noble cratur,
Which serves for lamplight all night in the dark,
While the sun only shines in the day which by natur
Wants no light at all, as ye all may remark."

"Budget of Paradoxes"—De Morgan

Perhaps the most notable indication of a return to normal conditions in illuminating engineering is to be found in the re-convention in Paris of the International Commission on Illumination in July of this year. The various countries represented and the character of the personnel who represented them insured a consideration of the questions presented for discussion which will be accepted as authoritative throughout the world. The decisions arrived at on the definitions of three of the fundamental ideas of illumination and the corresponding units constitutes a step in international progress which will be welcomed as establishing a beginning of international agreement which it is hoped will grow until there is universal concordance on all those quantities and units which make up the foundations of illuminating engineering.

Developments in light sources have not been marked although advances have been made in lamps for special purposes, more particularly in the electrical field. The war greatly stimulated progress in searchlight construction and improvements are

*Report presented before the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., Sept. 26-29, 1921.

The papers and discussions included in our own TRANSACTIONS are not, in general, referred to in this Report, it being taken for granted that members keep themselves advised of the contents of the TRANSACTIONS.

continuing. The enormous growth of the moving picture industry, both in production and exhibition has naturally inspired and brought out much progress in the methods of taking the films, of lighting the sets, in the machinery for projecting the pictures, and in the lighting conditions in the theatres.

While lack of funds has retarded normal growth in street lighting, many cities have proceeded with their programs of expansion and two new types of street lighting units have been reported, both of which have been designed especially for the purpose of giving an extended distribution up and down the highway. In other exterior illumination, sign lighting seems to have made the most advance, the use of higher candlepower lamps, particularly in blue bulbs having resulted in signs whose whiteness and prominence is in marked distinction to those equipped with low candlepower bulbs. The use of color in sign lighting has also contributed to its development.

Standardization of fixture accessories, such as plugs and outlets, as well as fixture parts, constitutes a big step in progress which will be greatly appreciated by the householder, as well as by the dealer and manufacturer. Greater attention to the problem of keeping glassware clean has resulted in the production of numerous units of the totally enclosed type.

The resumption of normal postal conditions between this country and Germany has made it possible to report on progress in that country and it should be noted that development seems to be going on apparently as vigorously as before the war. In other foreign countries the coal shortage has accelerated changes from gas to electricity, although in Paris enough relief in the coal situation was reached to warrant the putting of 14,000 gas lamps back into commission. It is reported[1] that in at least 200 cities in the 18 provinces of China proper there are lighting plants.

Attention has been called to the fact that the Stevenson family were light-house builders and that Robert Louis Stevenson, the great Scottish novelist at the age of 21 received a silver medal for a pamphlet on light-house illumination.[2] It may be of interest that the American novelist F. Hopkinson Smith was also a light-house keeper.

[1] *Elec. Rev.* (U. S.), July 23, 1921, p. 137.
[2] *Sci. Amer.*, Apr. 2, 1921, p. 263.

The Committee desire to thank those who have contributed information and the publishers of the journals whose columns have been freely consulted.

Respectfully submitted,

FRANCIS E. CADY, *Chairman,*

GEO. S. CRAMPTON, F. R. MISTERSKY,
OSCAR H. FOGG, W. E. SAUNDERS.

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GAS.

While 1916 was the occasion of a celebration of the centenary of gas lighting, because of its introduction in Baltimore in 1816, it has been claimed[3] that 1920 should be considered the real centenary since prior to 1820 its use was still tentative and it was not until that year when it was introduced in Paris by Frederick Winsor, that it could be said to have passed from the experimental stage to one of demonstrated value. The invention in 1920 of the fish-tail burner did much to support this contention.

From returns made by 360 gas companies to the American Gas Association[4] and information derived from various sources it has been estimated that the production of artificial gas in 1919 in the United States totaled 322,300,000 M cu. ft. Its use was divided as follows: for illumination, 22.28 per cent; other domestic uses, 50.49 per cent; industrial purposes, 23.46 per cent; other uses not classified, 3.77 per cent. Less than 1 per cent was used for street lighting. The number of incandescent burners in use for illumination (not including arc lamps or street-lamp burners) was given as 9,850,000. About 34 per cent of the gas companies maintained or furnished street lighting, all at low pressure and 11 per cent of the combination gas-and-electric companies furnish gas street lighting, all low pressure with the exception of one company which maintains 6 high-pressure lamps and 518 low-pressure.

[3]*Sci. Amer.*, Nov. 27, 1920, p. 544.
[4]*Gas Rec.*, Dec. 8, 1920, p. 60; Jan. 26, 1921, p. 49.

In England, according to a report[5] made in December to the British Illuminating Engineering Society, "recent improvements have been principally directed to increasing the efficiency in candlepower of both out-door and in-door high-power low-pressure lamps on the superheated principle by using a multiple of small burners (which dispenses with the need for inner glass cylinders), thereby reducing the cost of maintenance"........ "Standardization is being carried out by manufacturers as far as possible in regard to the sizes of glassware."

A new illuminant has been derived[6] from crude naphthaline, which, compressed while warm into cakes, is activated by fusing it and stirring it up with small quantities of very finely divided or else readily fusible metals, such as sodium, potassium, etc. Naphthaline thus prepared and while still in a fused condition is united with hydrogen by means of catalyzers in a continuously carried-on process with compression vats. It is changed into hydro-naphthaline and the latter is then distilled in vacuo. Among the resultant products is one known as deka-hydro-naphthaline or "dekalin," for short. This oil can be burned in any perfectly clean kerosene lamp and is said to yield a bright flame without either smoke or odor, and is economical and safe, since the ignition point of dekalin is very high.

The results of an extended investigation of the effect on the illuminating power of quality of gas as determined by various mixtures has been reported[7] in Germany. Measurements were made using both upright and inverted mantles and of the zonular spherical and mean horizontal candlepower.

Under date of Dec. 7, 1920, the Bureau of Standards issued[8] the 4th edition of its circular on Standards for Gas Service. The sections on "Heating Value" and "Candlepower" have been rewritten. The adoption or continuance of old candlepower regulations is not encouraged.

Burners.—It was reported to the Council of the British Gas Industries[9] at their annual meeting in November that lighting burner manufacturers have provided means of regulation for a

[5]*Gas Jour.*, Dec. 22, 1920, p. 707.
[6]*Sci. Amer. Mo.*, July 1921, p. 65.
[7]*Das Gas u. Wasserfach*, May 14, 1921, p. 309.
[8]*Am. Gas Eng. Jour.*, Feb. 26, 1921, p 192.
[9]*Gas Jour.*, Nov. 24, 1920, p. 449.

large range of gas qualities, and are arranging with the London Illuminating Engineering Society for the formation of a Joint Committee to keep in touch with all developments in gas lighting.

The oil shortage and other causes which have operated to make gas companies produce a lower candlepower output have also uncovered[10] a surprising number of open-flame burners. Up to the end of July (1920) about 80,000 mantle burners were given out in Baltimore to replace those of the open-flame type, and it has been estimated that Philadelphia will have 200,000 tips to replace.

A diminutive mantle has been designed[11] for use on light buoys in localities subject to rough seas. It uses only ⅝ cu. ft. of oil gas per hour and the reservoir is charged with a supply sufficient to last six months without renewal or attention. It emits 22 c. p. and it is claimed that the rays of light are so concentrated that it is visible for nine miles in clear weather. The mantle and burner are mounted on a pan-like reservoir, and the life of the mantle is given as more than one year. A new burner accessory[12] is made of fused opalescent silica and is employed both as a mantle protector and light intensifier. It is able to stand both great heat and great changes in temperature. The protectors are placed in close juxtaposition to the mantle, thereby increasing the flame temperature of the gas at the ignition point and consequently the temperature of the mantle fabric. It is claimed that with low pressure gas an output of 43 candles per cu. ft. of gas consumed per hour has been obtained. The burners to which this accessory has been attached have been especially constructed to suit any quality of gas.

Automatic Lighting and Extinguishing.—A new automatic gas lighter and extinguisher[13] of the pressure type has been described. It consists of a cup suspended in glycerin and communicating with the gas conduit. A progressive lowering of the pressure by 75 to 80 mm. (of water) ends by raising the cup which carries with it a tubular stop-cock plunged in a trough of mercury and controlling the passage of gas to the burner. When

[10] *Gas Age*, Sept. 10, 1920, p. 185.
[11] *Pop. Mech.*, April 1921, p. 543.
[12] *Ill. Eng.* (Lond.), Jan. 1921, p. 20.
[13] *C. R.*, Feb. 14, 1921, p. 372.

the cup is at the top of its course, the tube emerges from the mercury and permits the free flow of gas which is ignited by a pilot light. When the pressure returns to normal the cup is prevented from falling by a hook connected to a lever system. The light is extinguished by a lowering of the pressure as before, which makes the hook mechanism release the cup and close the gas passage. A third suppression returns the hook mechanism to its original position. It is claimed that the device does not contain any spring, any blow-valve, or any mechanism liable to get out of order or to break; that it will operate at any rate; that the rate and amount of suppression is too small to cause extinction of pilot lights; The tightness of joints is assured; the liquids employed will not congeal in winter weather and the materials of which it is made are not attacked chemically by the gas. Various methods of lighting gas street lights are in vogue in England.[14] A report has been made on three systems used in one locality: lighting by hand, by the pressure-wave system, and the clockwork type for outlying districts. With the pressure-wave system, the percentage of night failures was found to be 7.4. To obtain satisfactory results the mains and services must be adequate. The clockwork system gave 2.67 per cent failures, many of which were due to byepass troubles. The weakness of clock controllers was said to be variations in the time of lighting up. The wages-cost per lamp for hand lighting averaged twice the cost under the three combined systems.

Calorific Standards.—The tendency[15] in this country has been not only to eliminate the candlepower standard in the comparatively few places where it is still in force, in favor of the heat unit, but also to reduce the number of heat units required. Agitation for this purpose, *i. e.*, lowering the B. t. u. standard, continues.[16] Among others the following advantages have been suggested: (1) greater production per unit of raw material used; (2) reduction in the operating cost per 1,000 cu. ft.; (3) installing of more efficient methods of manufacture; (4) freedom from the use of gas oil; (5) extension of the usefulness of gas, notably in house heating; (6) added incentive to research

[14] *Gas Jour.*, Aug. 11, 1920, p. 296.
[15] *Gas Age*, Nov. 25, 1920, p. 409.
[16] *Gas Rec.*, Oct. 13, 1920, p. 33.

in the gas industry; (7) possible greater yields of by-products; (8) probably less condensation of hydro-carbons and less naphthalene stoppage; (9) expectation of a gas of higher flame temperature.

During the past two years, the American Gas Association has been collecting data on heating-value standards defining the quality of gas to be distributed to consumers in the United States. The resulting information has been put in a report[17] and shows in twenty state-standards a range from 475 to 650 B. t. u. and in 58 municipality requirements, a range from 500 to 625 B. t. u. This report capitulates the advantages of a lower standard as *a,* reduction of wasteful use of oil and coal necessary for the manufacture of high-candlepower gas; *b,* making available for gas purposes certain low-grade coals and oils hitherto precluded; *c,* lessening the congestion of transportation facilities by reduction in the amount of shipments required. An appendix to the report shows that as a result of two years' trial in Massachusetts by changing from a 16 c. p. to a 528 B. t. u. standard, the gas companies were enabled to reduce the amount of gas oil used by 15 per cent.

In Baltimore the Public Service Commission[18] has reduced the standard of gas from 550 to 500 B. t. u. In Seattle the oil shortage led the State Utilities Commission to grant a 30-day experimental period, during which the standard was reduced from 600 to 520 B. t. u. The Public Service Commission of Montana[19] has ruled 450 B. t. u. as the calorific standard for that state. In New Jersey it has been reduced from 600 to 525.[20] The result in the case of one company operating a straight coal-gas plant was a considerable improvement in customer service, although the saving in holder cost was found to be very slight.

As forecasted in last year's Report, the British Parliament on August 4, 1920, passed the Gas Regulation Act,[21] establishing

[17] *Gas Age,* Dec. 25, 1920, p. 507.
[18] *Gas Age,* Oct. 25, 1920, p. 321.
[19] *Gas Rec.,* Aug. 25, 1920, p. 36.
[20] *Gas Rec.,* Feb. 9, 1921, p. 15.
[21] *Elec. Times,* Aug. 19, 1920, p. 139.
Gas Age, Sept. 10, 1920, p. 184.

a new basis for charging for gas, using its calorific value instead of its volume. The new unit is christened the "Therm" and it represents 100,000 British Thermal Units, which, with gas at 500 B. t. u. per cu. ft. would make the former unit of 1,000 cu. ft. contain 5 Therms. The Act also gives authority to the British Board of Trade to place all gas companies in Great Britain on a heat-unit basis.

It has been suggested[22] that a practical indicator of the composition and calorific value of gas to be manufactured is a 70 c. p. upright "C" mantle, working at an output of 30 candles per 1,000 B. t. u. supplied. Research has shown that a gas that will give this light with an ordinary upright burner under working conditions, is quite suitable for giving efficient results for other purposes. The 30 candles per 1,000 B. t. u. is taken as a compromise between laboratory and working conditions. In this connection, it has been pointed out that the above standard will not be lowered by the presence of inerts to the extent of 35 per cent of nitrogen or 10 per cent of carbon dioxide.

INCANDESCENT LAMPS.

Until the limit of efficiency in the transformation of electrical energy into luminous radiation has been reached, the search for a more efficient filament material for electric incandescent lamps will continue. When the period just prior to 1907, the year in which tungsten lamps came into practical use, is considered, and it is realized that in three or four years no less than four successive improvements were made starting with the gem, and running through osmium, and tantalum to tungsten, and thereby pushing the watts per candle consumption from 3.1 to 1, it would seem that the further decrease to 0.4 or 0.5 during the past 14 years was not very great. While waiting for the discovery of some element which will again revolutionize the industry, the tungsten lamp is being steadily improved, new lamps for various classes of service are being produced from year to year, and the regular standardized types are being made more uniform in character and life performance.

[22] *Gas Jour.*, Jan. 12, 1921, p. 85.

Manufacture.—The output of carbon-filament lamps had decreased in 1920 to only 4.3 per cent of the total number of lamps made, as compared to 7 per cent in 1919[23] and 97 per cent in 1907. It is expected that 1921 will see the practical elimination of this type of lamp as far as manufacture in this country is concerned. The number of gas-filled tungsten lamps continues to show an increase, being 20 per cent of all tungsten lamps disposed of in 1920, as against 19 per cent in 1919 and 13.7 per cent in 1918. Statistics from Germany[24] show that the number of carbon-filament lamps increased from 1918-19 to 1919-20 from 3,870,000 to 4,070,000, while for the same period metal filament lamps decreased from 44,350,000 to 43,730,000. According to Japanese officials, the total number[25] of electric incandescent lamps in service in the Island Empire is 12,210,000, an increase of 800 per cent since 1910. There are 180 lamps to every 100 homes or a little more than one lamp to every five inhabitants. More than 1,600,000 are used in Tokyo, 800,000 in Osaka, 400,000 in Kioto, and 300,000 in Kobe.

In the United States, the average candlepower, watts and efficiency, all show an increase due to the greater proportion of gas-filled lamps used, since these lamps are higher in each respect than vacuum lamps. The effort to standardize the voltages, 110, 115, and 125 has progressed so that 80 per cent of the present demand is for them and of 481 central stations reporting, 96 per cent are employing these three voltages exclusively, whereas the corresponding figure for 1920 was 79 per cent, indicating again progress in standardization.

Types.—New lamps have been reported[26] in the street series, stereopticon and sign classes. For the first mentioned a 2500 c. p., 20 amp. unit has been made available and constitutes the highest candle-power source in this type. It is designed for 20 amperes derived by means of a compensator or transformer from regular alternating current series circuits and has the same light centre length as the other street series compensator lamps. For stereopticon work a 300-watt, 28-32 volt gas-filled lamp in a short

[23]Report of Lamp Com., N. E. L. A., May, 1921.
[24]*Das Gas u. Wasserfach,* Mar. 5, 1920, p. 158.
[25]*Elec. Wld.,* Feb. 5, 1921, p. 338.
[26]Report of Lamp Com. N. E. L. A., May, 1921.

tubular bulb has been listed. A decided advance in the sign-lighting field has been made by the production of 25 and 50-watt, 110-125 volt vacuum lamps in short pear-shaped bluish colored bulbs with the filament in a plane perpendicular to the lamp axis, thus giving a maximum candlepower in the direction of the tip. The design is somewhat similar to the old "downward light" carbon-filament lamps of the earlier days. The support is rigid and the lamp as a whole rugged, and adapted to the severe conditions of vibration often present in sign structures. The filament being mounted near the base permits the lamps to be used in troughs designed for 5 and 10-watt lamps.

Lamps of special design continue to appear,[27] and one has been described having two filaments, the second being put in service when the first has burned out. The result is accomplished by screwing and unscrewing a cap in the base of the lamp. A further modification[28] introduces three instead of two filaments, a three contact fitting being provided in the base. By making the filament in a more concentrated shape, more accurate focussing and a better beam candlepower distribution is being obtained[29] with gas-filled tungsten automobile headlight lamps. For automobile lamps in general voltage conditions in actual service have been studied with many makes of cars both old and new and as a result changes will be made which it is expected will result in increased efficiency and higher brilliancy.

Specifications.—Two years ago attention was called to the persistent use in England of the term "half-watt" in referring to the gas-filled tungsten lamp. This misnomer is gradually being dropped[30] and the technical press has noted the desirability of the correct designation. In Germany, the term is still common,[31] and there is no apparent effort being made to correct it.

The lumen rating has been used in this country in the design and testing of gas-filled tungsten lamps of the street-series types, but because of existing street-lighting contracts, which specified candlepower, has not completely superceded the candlepower rating. As the lumen rating is so much more exact than the old

[27]*Elec. Wld.*, Sept. 4, 1920, p. 503.
[28]*Pop. Mech.*, July, 1921, p. 116.
[29]*Gen. Elec. Rev.*, Jan., 1921, p. 42.
[30]*Elec. Rev.* (Lond.), Oct. 15, 1920, p. 483.
Elec., Nov. 19, 1920, p. 583.
[31]*Elek. Anz.*, May 11, 1921, p. 468.

method, a movement[32] is on foot to label street-series lamps in lumens, the candlepower rating being also given on the label to avoid conflict. It is hoped to have contracts changed so that the lumen rating will be specified. On January first, the lumen and lumens-per-watt were adopted by the larger lamp manufacturers as the official units in which to express the light output and efficiency of their product. This constitutes a big step in the direction of the universal adoption of these units, a goal towards which the Illuminating Engineering Society has been working for a number of years.

The Standard Specifications for Incandescent Lamps,[33] issued by the Bureau of Standards, have in the past provided for the evaluation of lamp performance in terms of the "useful life," defined as the life to 80 per cent of the initial candlepower or previous failure. As this method of rating has been outgrown the specifications have been revised during the past year and a feature of the revision is the separation of performance and inherent lamp qualities from lamp efficiencies and life. Lamp performance is evaluated in terms of average total life and mean efficiency during life, or on the basis of the average total life corrected to a stipulated mean efficiency during total life. Another significant change in the specifications is the abandonment, except as a primary standard, of the candlepower. All light measurements are expressed in lumens.

Properties.—The question whether it is safe to use gas-filled tungsten lamps in flour mills, grain elevators and other places where the air is filled with dust has been studied.[34] The bulb temperature for gas-filled lamps being higher than in vacuum lamps it was found that dusts would smoke readily if allowed to collect on the former while they would not on the latter. The limits of smoking temperature have been found to be 140° C. to 166° C. without regard to the kind of dust or its ignition temperature. These limits are about the working temperature of the lower wattage gas-filled bulbs (75 and 100 watts), but 56-83°

[32]Report of Lamp Com., N. E. L. A., May, 1921.

[33]Report of Lamp Com., N. E. L. A., May, 1921.

[34]*Elec. Wld.*, Jan. 22, 1921, p. 191.
Elec. Rev. (U. S.), July 30, 1921, p. 165.

higher than the bulb temperatures of vacuum lamps. But the lowest ignition temperatures were about 260° C., and, hence, extra chaffy dusts would have to be raised 167° before taking fire from vacuum lamp bulbs, and 83° C. before taking fire from 75 and 100-watt gas-filled lamp bulbs. It was found possible to start a fire on the larger gas-filled bulbs, but not with the 75 and 100-watt, or the vacuum lamps up to and including the 100-watt size.

Work has been done[35] on the spectral distribution from a lamp containing a tungsten spiral or tantalum band in an atmosphere of nitrogen or argon, with a quartz window in the side of the bulb, the temperature being raised above that normally used in gas-filled lamps. As has been found before a continuous spectrum in the ultra-violet was obtained which is sufficient for many purposes. An extension[36] of the data in the relation between true and color temperature and specific consumption of incandescent lamps has been obtained by measurements on gas-filled lamps of the 500 and 1000-watt sizes and the 100-watt stereopticon and 900-watt movie lamps. The last named at 0.46 watts per spherical candlepower has a true temperature 3290° K and a color temperature 3,220° K.

ARC LAMPS.

From the paucity of published information, it would appear that there have been no developments in the design and construction of carbon arc lamps, except for search-light work, which will be referred to under the heading "Lamps for Projection Purposes." Whether this is due to the continual encroachment of the incandescent lamp on the fields formerly dominated by the arc lamp remains to be seen. The development several years ago of the high-intensity arc where the vapor in the positive carbon crater has a brilliancy ranging from 500 to 900 candles per sq. mm., with a consequent high actinic value has brought about an increased use of this arc in moving picture studios. Improvements in high candlepower incandescent lamps, together with special reflectors have tended to further supplant the arc lamp in street lighting.

[35] *Zeit. f. tech. Phys.*, No. 10, 1920, p. 224.
[36] *Jour. Frank. Inst.*, July, 1921, p. 109.

Adopting a special Y-shaped arrangement, two negatives to one carbon, an experimenter has obtained[37] results which indicate that the crater area of an arc is proportional to the total current, the current density being constant and 0.746 amp. per sq. mm. This result is contrary to that found by Mrs. Ayrton and other former workers in this field. It was pointed out that as Forrest has found a constant brightness for the carbon arc of from 172 to 174 candles per sq. mm., if a carbon arc is suitably arranged and the current accurately measured, the candlepower should be accurately known and be, in fact, 232 candles per ampere. It was conjectured that the constancy of the candlepower thus controlled should be within one per cent, and thus again bring forward the carbon arc as a contender for the position of a primary standard of light.

Experimental work has also been done on the effect[38] on the crater of a carbon arc of additional radiation supplied by another arc and reflected to the first through a double-mirror system. A drop in temperature was found, but an increase in luminous intensity, which corresponded to an increase in the crater area.

Vapor.—The introduction of quartz tubes for mercury vapor lamps marked an epoch in this type of illuminant. But it brought difficulties of construction, one of the principle ones being a permanent seal at the leading-in wires. As the result of the development[39] of a means of connecting quartz through intermediate steps of glasses of increasing coefficients of expansion to a glass fused directly to a metal lead-in wire and forming with it a permanent vacuum-tight seal which would stand high temperatures, it has been found possible to use an anode electrode of infusible tungsten instead of mercury and a greatly simplified quartz burner is the result. It is essentially a vacuum arc in a fused quartz chamber. Owing to the ability of the leading-in wires to stand high temperatures, it does not require the elaborate cooling devices formerly used in this type of lamp.

The low-candlepower neon vapor lamp has been introduced in England[40] as a night light. It is rated at ¼ c. p., 110 volts

[37] *Elec.*, Jan. 28, 1921, p. 120.
[38] *E. T. Z.*, Apr. 14, 1921, p. 375.
[39] *Gen. Elec. Rev.*, Nov., 1920, p. 909.
[40] *Elec. Rev.* (Lond.), June 10, 1921, p. 764.

and upwards on A. C. and 150 volts and upwards for D. C. and consumes 5 watts. It is claimed that the life is more than a thousand hours, the only source of deterioration being the gradual blackening of the bulb. It is suggested for use in emergency lighting systems, hospitals, nurseries, and the like. Neon lamps are also being made in Germany.[41] One size is designed for use on 220 volt A. C. systems with a current of 1 ampere, with a suitable resistance in the circuit. In order to strike the arc a vacuum interrupter is connected in parallel with the lamp, a small choking coil being inserted in the common portion of the circuit. An inductive impulse set up by the automatic action of the interrupter by means of a magnetic coil, causes a discharge through the lamp. It is claimed to operate at 0.5 w. p. c. and can be started and stopped as often as 400 times a minute. A great variety of others have been placed on the market for both A. C. and D. C. The resistance of such lamps, as defined by voltage impressed and current passed is not fixed, but varies with the intensity of the discharge. A lamp for 20 milli-amperes D. C. has about 10,000 ohms resistance. In general, a consumption of from 4 to 5 watts is sufficient. Among the many uses suggested are: in parallel with a fuse to detect and show burnout; position indicator for switches; distant indicator of the condition of a motor; in series with a condenser to limit the discharge energy; in series with an X-ray tube to show by its luminosity the current passing through the tube, etc.

Additional experiments have been made[42] on the production of low voltage arcs in an atmosphere of mercury vapor. It has been shown that there is a linear relation between the striking voltage and the current through the cathode for the larger currents. Tungsten cathodes were found to produce lower arcs than lime-coated platinum cathodes. A striking voltage as low as 3.2 volts was obtained with the former as against 4.9 with the latter.

LAMPS FOR PROJECTION PURPOSES.

A decided innovation in the tubular type of hand or flash lamps consists[43] in the addition of a device whereby the light can

[41] *Elec. Rev.* (Lond.), Mar. 18, 1921, p. 340.
E. T. Z., Feb. 10, 1921, p. 121.
[42] *Phys. Rev.*, Nov., 1920, p. 375.
[43] *Elec. Rev.* (U. S.), May 7, 1921, p. 752.

be concentrated or "spotted" at various distances. The result is accomplished by moving the miniature lamp bulb along the axis of the parabolic reflector by turning a cap at the end. The larger size is claimed to have a range of 300 ft. The case is also provided with a small compartment to carry extra lamps and is stamped to show the renewal type of battery and lamp required.

Hand Lamps.—The flashlight supplied with current by a small hand-operated dynamo used by the Germans during the war and subsequently developed in this country, has been taken up by the French.[44] The lamp unit resembles a small black box and is suspended from the neck of the owner, the dynamo being actuated by pulling a chain. Electric lamps for bicycles are not a novelty, but in Germany an extension of the hand-operated dynamo referred to above has been applied[45] to the bicycle problem. The dynamo is fixed on the front fork so that the small driving wheel will lie in the centre line of the tire. A regulator is provided to guard against over-voltage. A hand lantern made to be particularly useful in cases of fog or smoke has been brought[46] out in which all working parts are made of aluminium, and the silvered reflector is large. A focusing device is added and the hook-shaped handle makes it convenient to carry or hang to any accessible projection. Two dry cells are used.

Locomotive Head-lamps.—The restricted use of electricity in Germany[47] is evidenced by the development of acetylene lamps for use as locomotive head-lamps and for railroad hand lanterns. The burning period is given as from 8 to 10 hours.

Spot-lamps.—An improved spot-lamp for theatre use has a sliding condenser by means of which projection can be made even when there is a considerable angle, as when the projection booth is at the top of a gallery.[48] The top carbon has a horizontal as well as the usual vertical movement so that the carbon may at all times be set for maximum efficiency. A spot-lamp has been devised for use in photographic studios which is claimed[49] to produce lighting effects similar to those obtained in motion-

[44] *Pop. Mech.*, June, 1921, p. 886.
[45] *Helios*, Apr. 23, 1921, p. 1618.
[46] *Elec. Rec.*, July, 1921, p. 23.
[47] *Licht u. Lampe*, Apr. 21, 1921, p. 194.
[48] *Elec. Rev.* (U. S.), Sep. 11, 1921, p. 300.
[49] *Elec. Rec.*, Nov., 1920, p. 313.

picture work. A 400-watt, concentrated filament gas-filled tungsten lamp furnishes the light, and for focusing purposes, the lamp socket is fastened to a sliding carriage having a long handle.

Signal Lamps.—Some years ago a reference was made in this Report to a special signal lamp designated as an accompaniment of the theodolite in survey work on lines up to 150 miles. (241.5 km.) This lamp has been further improved[50] so that now a battery of only three dry cells is required where six were formerly used. The lamp has a consumption of approximately two watts, at 0.6 of an ampere and is said to have an apparent beam candlepower of 17,500 at a distance of 100 ft. (30.4 m.) As an aid to motorists and as a means of controlling traffic on highways, traffic engineers have proposed[51] the use of flashing lamps as danger and signal beacons. Eighty flashes per minute and the standard railroad colors, red, yellow and green are recommended. Results have been given[52] of work done during the war on the flashing speeds of incandescent lamps used for signalling purposes. It was found that for lamps of equal voltage, life and luminous flux, a tungsten filament responds more rapidly than carbon during the heating portion, by a factor of 2.5. It was also found that the speed of the flash was greater the higher the maximum temperature of the flash; the smaller the filament, the less the resistance external to the lamp; and that for lamps of the same open filament construction, the same luminous flux and the same average life at a fixed voltage, the speed of flashing is greater the greater the gas loss. A ribbon tungsten filament in argon was found to be quicker than a wire tungsten in nitrogen in the proportion 1.6 to 1.25.

Search-lamps.—As a result of mathematical analysis of the light received from a perfectly diffusing circular disk by another parallel and coaxial disk of given diameter placed at a given distance away, it would appear[53] that, in general, little advantage is gained by inclining the negative electrode as compared with the use of coaxial carbons in search-lamps where the object is to prevent the obscuration occurring when a shadow is cast on the

[50] *Sci. Amer.*, June 4, 1921, p. 453.
[51] *Elec. Wld.*, Mar. 5, 1921, p. 582.
[52] *Jour. Frank. Inst.*, Feb., 1921, p. 231.
[53] *Ill. Eng.* (Lond.), Sept. 1921, p. 252.

negative electrode. This does not apply if the negative electrode is very bulky or increased so as to bring the obscuring object outside the angle embraced by the search-lamp mirror. Another extensive mathematical study[54] has been made of the light flux and distribution in the beam of a search-lamp having a parabolic mirror.

Reference should be made to an elaborate discussion[55] of the developments of the U. S. Army search-lamps, in which it is pointed out among other things that a radical re-design in mechanisms for barrel search-lamps has resulted in the substitution of aluminum in place of bronze or cast iron and in stiffening up the pillar for supporting the carbons.

An improvement in the Beck type of high-intensity arc lamp for projection purposes is obtained[56] by using greater currents with smaller carbons of the cored type, in which the metal fluorides are replaced by oxides. The area of the carbons is reduced to about one-fifth that of the ordinary type with a resultant surface brightness of 1260 candles per sq. mm. A report has been published[57] of developments made during the war period in high current arcs between plain carbons as used in searchlights. Experience had shown that a reasonably smooth arc would be obtained with a current density of about 0.15 amp. per sq. mm. of the area of the cross section of the positive carbon. By using a magnetic field it was found possible to increase this figure to 0.35 amp. per sq. mm. The result on the total flux of light was an increase of 50 per cent. The positive carbons were copper plated. Copper coating was also applied to the negatives, which were cored. Tests of the illumination across the diameter of the search-lamp beams produced by arcs between electrodes of equal diameter and carrying equal currents at a range of 13,000 ft. (3968 m.) gave a ratio of 1 : 73 : 40, all being solid carbons, but the first plain and the other two impregnated. It should be emphasized that the above results would not apply to high-intensity arcs, such as the Sperry and Beck.

[54]*E. T. Z.*, Dec. 9, 1920, p. 973.
[55]*Jour. Frank. Inst.*, Oct., 1920, p. 509.
[56]*Central-Zeit. f. Optik. mech.*, Oct. 10, 1920.
Tech. Rev., Mar. 29, 1921, p. 299.
[57]*Jour. Inst. of E. E.*, Aug., 1920, p. 652.

An unusual arrangement for a searchlight installation[58] is found on some German warships, where the instrument itself is placed in a protected position inside the hull, while the light passes up through the hollow steel mast of the ship and is projected by a mirror at the top.

Automobile Head-lamps.—New head-lamps for automobiles continue to appear[59]. Among the recent designs is one having two bulbs, one above the other, the upper fitted with a reflector of the standard parabolic shape, the lower with only the bottom half of such a reflector. The lower bulbs are not visible and are used for city traffic. They may be dimmed to give a low consumption for parking purposes.

What is claimed to be a near approach to a perfect non-glaring automobile head-lamp is reported[60] from England. It has a cartridge-type case containing an elaborate system of ten lenses and two prismatic reflecting condensers arranged at the front and rear of the case. Another non-glaring head-lamp attachment emanating from England,[61] consists of a grid made up of thin aluminium plates crossing at right angles and forming a network of squaure tunnels about ⅜ in. (0.95 cm.) wide and 2 in. (5.08 cm.) long. These are held in a frame which fits onto the lamp. The result is that the beam is concentrated about 4 or 5 ft. (1.2 m. to 1.5 m.) in front of the lamp, whence it widens out to give sufficient light laterally.

Movie Lamps.—Efforts have been made for a number of years to perfect a high-current arc lamp for moving-picture projection, in which the upper carbon is horizontal and the lower inclined at an obtuse angle. Such lamps have been used for currents up to 30 amperes, but at higher currents it has been found impossible to keep the arc sufficiently steady. Success in overcoming this difficulty is claimed[62] for a new lamp brought out in Germany for both A. C. and D. C. and current strengths up to 80 amperes. The reason is said to be due to the almost vertical position of the positive crater and to the fact the arc does not break out laterally and the arc flame rises almost vertically and

[58] *Sci. Amer.*, Dec. 18, 1920, p. 607.
[59] *Pop. Mech.*, Nov., 1920, p. 759.
[60] *Pop. Mech.*, June, 1921, p. 919.
[61] *Sci. Amer.*, June 4, 1921, p. 443.
[62] *Helios*, Nov. 7, 1920, p. 4243.

does not tend to strike the condenser. This is accomplished by a carefully designed and syntonized magnet which constantly controls, centers and keeps the arc in an upright position. Among the constructional improvements are a reduction of the hand wheels controlling the arc from 5 or 7 to 3; an arrangement of the carbon holders so that they are withdrawn from the heat of the arc and the use of three pedestals through which all parts have multiple supports. A considerable improvement in light flux for the same wattage consumption, and a more uniform light distribution beam are other claimed advantages. The same development has just been announced[63] in this country. Automatic regulation of the arc length is obtained through a motor whose speed is dependent on the arc voltage. The negative carbon is inclined at an angle of 60 degrees to the horizontal. This lamp has only two hand adjustments.

An improved stereopticon lamp is reported[64] from France. It is used for opaque projection and is intended to be used in a light room. The features of the instrument are the arrangement of the reflectors behind the source of light which may be of any type, and the short focus lenses employed to concentrate further this light upon the object. The lamp house has a powerful condenser, the balance of the optical system being contained in a separate unit.

Comparisons have been made as the result[65] of tests on ground and unground glass reflectors used in head-lamps, which seem to show that the beam-candlepower increases only approximately as the square of the reflection diameter and that the ground and polished reflectors average about 50 per cent higher in beam candlepower than the unground for the same diameter and have a lower cost per candle.

The old-fashioned lime light, with certain modifications, has been revived[66] in Germany for cinema projection, owing to the restrictions on the use of electricity and its relatively high cost. The original piece of lime has been replaced by a small disk about 0.5 in. (1.27 cm.) in diameter, made of rare earths. It is heated

[63]*Mov. Pic. Wld.*, July 23, 1921, p. 447.
[64]*Sci. Amer.*, July 9, 1921, p. 29.
[65]*Elec. Ry. Jour.*, Sept. 18, 1920, p. 556.
[66]*Das Echo, Deutsche Export Revue*, Sept. 30, 1920.
[66]*Tech. Rev.*, Dec. 21, 1920, p. 397.

by an oxy-acetylene flame. The acetylene is produced from carbide and large volumes of oxygen are obtained by gently heating a patented material, sold in small metal tubes enclosed in the ordinary steel bottles. It is said to have been extensively adopted in German theatres and is especially adapted to travelling shows, as the complete equipment with spare oxygen tubes can be packed in a box 1¾ ft. x 1¼ ft. x 1 ft., (0.53 m. x 0.38 m. x 0.30 m.), weighing 72 pounds. A tube of oxygen lasts 2 hours and the cost of operation is about one-third that of electricity.

A new screen for moving-picture projection is designed[67] for use in daylight and employs the principle of transmission. The projection machine is placed behind the screen in an enclosure from which all other light is excluded. It is claimed that the diffusion is so regular that an even luminosity is obtained, while the light source is invisible. Under reflected light the screen shows a deep black color.

In place of the shutter and intermittent film-feeding gear of the ordinary motion picture projector, a new device[68] employs a continuously rotating ring of mirrors. The facets on the mirrors are so arranged and set at such an angle that the two lights from the two partial film-pictures which are present at any instant at the opening, are separated and transposed into their correct positions on the screen and join up to form a complete image. There is no dark period and no over-lapping or dissolving of the successive pictures into each other, as the first picture disappears at precisely the same rate that the second takes its place. The film is run uniformly through the machine and the images are said to be clear and sharply defined.

Miner's Lamps.—As a result of ten years' experience with standard electric safety lamps for miners, a new unit[69] has been worked out. The essential features are a fitting for the cap, of aluminium, shaped to receive a silvered reflector, which is screwed to take the lens ring. The lamp holder is secured to the inner side of the cap fitting, and is connected to the battery through special

[67] *Engineering Progress*, July-Aug., 1920.
Sci. Amer. Mo., Jan., 1921, p. 87.
[68] *Elec. Rev.* (Lond.), Mar. 11, 1921, p. 331.
[69] *Elec. Rev.* (Lond.), July 2, 1920, p. 20.

contacts and a cable. The battery case is of heavily-tinned sheet iron coated with acid-proof paint. The connections to the electrodes are through spring plungers in ebonite blocks, to avoid the use of spring connections on the battery terminals. The cap is especially designed so that the weight is uniformly distributed on the head and the cable maintained in a central position at the back. The 2-volt, 0.5 amp. lamp has a nominal candlepower equal to 0.7 reflected candlepower, which gives a beam extending over an area of 10 ft. (3.04 m.) at a distance of 2½ ft. (0.76 m.) A flange-tight switch is fitted to the battery.

A research has been conducted[70] by the British Miner's Lamp Commission on the possibility of danger from the ignition through short circuits or otherwise of the celluloid used as cases for the batteries of miner's lamps. It was found that the ignited celluloid would not ignite fire-damp and would not produce fumes dangerous to health, but that it might cause enough pressure to burst the lamp case. This difficulty can be avoided by providing vent holes in the metal cases.

STREET LIGHTING.

A survey of the changes in street lighting in the principle cities of this country as shown by the reports of the engineers in charge, indicates to some extent a reflection of the business situation, as the statement of "no additions" is generally accompanied by "lack of funds" as the cause. The renewal of activities which started immediately after the close of the war has continued, and while many cities have adopted the policy of waiting for the resumption of normal business and for lower cost of materials and labor before increasing their street-lighting, others have forged ahead with their development work. A notable illustration of the latter condition is to be found in the case of Kansas City, Mo., which, will be referred to later. It is rather interesting to note that the principle cause given for curtailment in lighting in European cities is the coal shortage. In most cases this has caused a change from gas to electricity, rather than an actual decrease in the lighting equipment.

[70] *Elec.*, Mar. 18, 1921, p. 327.

The great variety in the methods of reporting on street lighting emphasizes the desirability of a standardized form which will show all the data needed by the illuminating engineer to get an adequate idea of an installation. Thus most reports give the total number and kind of lamp employed and many add the spacing or number of standards to the block and the height of the light centre. One report gives the number of miles of streets lighted by various sources, and another adds the candles per foot. Would it not be a useful addition to the practical accomplishments of the Illuminating Engineering Society to have the proper committee prepare such a standardized model form which would list the subjects on which data should be given, and distribute these forms to city engineers and others who are interested in street lighting information, so that future reports may be more comprehensive?

Reference should be made to the report[71] of the Street and Highway Lighting Division of the Lighting Sales Bureau of the N. E. L. A. Attention is there called to the fact that "Street lighting systems should form a part of the architectural development of every community and more thought should be given to the artistic design, as well as the efficiency of both fixtures and standards." In a discussion on the trend of practice in ornamental street lighting, it has been said[72] that the present tendency is toward single lamps with prismatic reflectors and toward higher mounting heights. Concrete posts are competing with cast iron for public favor in street lighting. Typical present practice is to employ mounting heights of 12 to 14 ft. (3.7 m. to 4.3 m.) although heights to 25 to 35 ft. (7.6 m. to 10.7 m.) occur in some of the large cities.

There is a growing use[73] of the type of street traffic signals which is made in the form of a low mound of concrete or other suitable material, not over a foot or two high, smoothly rounded to the edge, painted white, with stripes in some cases, for daylight observation and provided with red lenses, back of which are electric lamps for night use. Striking such mounds does not result in either danger to the machine or to the signal.

[71] Report of Street and Highway Division, N. E. L. A., May, 1921.

[72] *Elec. Wld.*, May 28, 1921, p. 1208.

[73] *Sci. Amer.*, May 28, 1921, p. 433.

Attention has been called[74] to the waste in the present methods of operating gas street lamps, owing to the hours of useless burning, just before and after darkness. The average period, during which the street gas lamps are burned daily is given as eleven hours, whereas they should be lit on the average for only nine hours. In Philadelphia alone, with 25,500 lamps, each consuming 14,400 cu. ft. per year the loss amounts to over $60,000.00.

Considerable attention is being paid to improvements in street lighting in foreign countries, as will be seen from the references following those describing new installations in the United States.

The Western Coast.—Seattle reports no changes in their lighting system and Portland has made changes only to the extent of increasing the number of arc lamps by 75. In San Francisco improvements have come to a standstill, largely due to the fact that the cost of street lighting has very materially increased through surcharges approved by the California Railroad Commission. In Los Angeles small installations of ornamental posts have been made both in the residential and business zone districts. A type of standard proposed in these business zones has a two-lamp concrete or cast-iron post, approximately 17 ft. (5.2 m.) to the lamp centre with 400 c. p. tungsten gas-filled lamps, the spacing being from 100 to 135 ft. (30.4 m. to 41.1 m.)

Utah.—Arrangements have been completed for the installation and maintenance[75] of an extension to the "White Way" lighting system of Salt Lake City. Six and six-tenths ornamental, luminous arc lamps provide the illumination, there being three to a standard, fourteen standards to the block, seven on either side of the street. The new district will contain 112 standards out of a total of 182, the whole covering two miles of streets, giving approximately 90 candles per foot of street lighted.

Colorado.—Negotiations are under way[76] in Denver to light the Williams Highway from the city limits of Golden to the summit of Lenkert Mountain, a distance of five miles. One

[74]*Gas Record*, Oct. 13, 1921, p. 24.
[75]*Elec. Wld.*, Jan. 29, 1920, p. 282.
Elec. Rev. (U. S.), Mar. 12, 1921, p. 416.
[76]*Elec. Wld.*, April 9, 1921, p. 831.

hundred and fifty 600-c. p. series incandescent lamps will be employed, mounted on 20 ft. (6.1 m.) posts, the lamp centers being 18 ft. (5.5 m) from the ground.

Middle West.—A big change in street lighting equipment has finally been decided upon in Kansas City,[77] Missouri. Five thousand six hundred gas lamps are to be replaced by 2600 electric lamps of the 600 c. p. size in the down town districts and 400 c. p. in the outlying parts. The city already had 5419 electric street lamps. Another new feature is an arrangement whereby the "White Way" lighting is to be operated on the same schedule as the regular street lamps.

The five-lamp cluster standards installed in Minneapolis five years ago have not proved to be very satisfactory from the standpoint of good illuminating engineering and a change in the equipment has been suggested,[78] which would direct more of the light rays toward the street and eliminate objectionable glare. An extension of the ornamental lighting system has been demanded and will be met by putting in some single-lamp 500-watt units.

Work has been started on the extension of the Fort Worth street lighting system[79] which will amount to an increase of 75 per cent when the eight hundred 300-watt lamps are installed in the southern section of the city. A new "White Way" system has been placed[80] in service in Oklahoma City.

Central States.—In Detroit, Michigan, since July 1, 1920, 442 enclosed A. C. arc lamps have been replaced by 4-amp., luminous arc lamps of the pendant type. One thousand, one hundred and seven (1107) lamps of this type have been installed in addition to those already in service. Some of these lamps have been added to improve the illumination in the down town districts, but the greater number have been fitted up in the outlying new residential sections. Forty-seven 4-amp. boulevard-type luminous arc lamps have been installed in Roosevelt Park. Plans are in preparation for the ensuing year for the installation of five hundred 4-amp. luminous arc lamps on over-

[77] *Elec. Wld.*, Mar. 5, 1921, p. 556.
[78] *Elec. Wld.*, April 9, 1921, p. 845.
[79] *Elec. Wld.*, Mar. 5, 1921, p. 556.
[80] *Elec. Rev.* (U. S.), July 9, 1921, p. 58.

head circuits and seven hundred and sixty 4-amp. lamps connected to underground circuits.

Additions to the regular street lamps in Cleveland have amounted to 112, and it is planned to add 400 lamps to the "White Way" lighting system during the coming year. An ornamental lighting system has been installed[81] in one of the parks, and replaces a former system using 250 c. p. gas-filled tungsten lamps spaced about 250 ft. (75 m.) apart on a standard which was a converted gas post and only 9 ft. (2.7 m.) high. The new units are suspended on ornamental bracket lantern posts, the globe being of the same type as that used in the "White Way" lighting of the city and containing interchangeable parts. Certain portions of the standards are also interchangeable. The lamp heights are approximately 20½ ft. (6.2 m.). The standards are spaced 200 ft. (60 m.) apart and carry 600 c. p. tungsten lamps. A special cleaning schedule has been arranged for.

A new lighting system has been laid out for Hamilton, Ohio, to replace[82] the old series enclosed arc lamps, which have come to be obsolete. One thousand and four hundred (1400) gas-filled tungsten lamps will be required, made up of the 1000 c. p. size in the business district, 600 c. p. on the main thoroughfares, 400 in the thickly settled residential portions, and 250 c. p. for the outlying parts and for the middle of blocks where the distance is too great for street-intersection lighting alone. At Lima, Ohio,[83] a new system is being put in consisting of 1000 standards with 1000 c. p. lamps.

Eastern States.—Two hundred of the globeless street-lighting standards described in the section on "Fixtures" have been installed in a residential district in Rochester,[84] N. Y. Wilkes-barre, Pa., is trying[85] out in its gas street lighting, an automatic lighting and extinguishing apparatus operated on the pressure-wave principle.

In Philadelphia there are at present in use 18,350 electric lamps, 25,480 free gas lamps, 11,364 paid-for gas lamps, and 9,901 gasoline lamps.

[81] *Elec. Wld.*, July 23, 1921, p. 157.
[82] *Elec. Wld.*, June 18, 1921, p. 1447.
[83] *Elec. Wld.*, July 23, 1921, p. 186.
[84] *Elec. Wld.*, June 18, 1921, p. 1430.
[85] *Am. Gas Eng. Jour.*, Jan. 1, 1921, p. 21.

The following table shows the number of lamps in the city of Boston up to and including June 1, 1921; with a similar statement for the year ending May 1, 1920, and a column showing the increase:

			June 1, 1921	May 1, 1920	Increase
Magnetite arc lamps	800 c. p.	Series	5352	5297	55
Magnetite arc lamps	800 c. p.	Multiple	26		
Incandescent	40 c. p.	Series	1893	1836	57
		Multiple	1449	1447	2
	60 c. p.	Series	743	730	13
		Multiple	555	567	—12
	100 c. p.	Series	3	3	
		Multiple	14	14	
	200 c. p.	Series	10	10	
	500 c. p.	Multiple	11	11	
Gas open flame F. A.			143	144	—1
Single-Mantle Gas Welsbach	60 c. p.		9710	9704	6

277 "White Way" lamps, Boulevard type, included in the magnetite arcs above quoted.

Canada.—Montreal, West, is to be lighted[86] by tungsten lamps on cast-iron ornamental pedestals which will total 280 and are said to be sufficient to light all the streets. The street lighting system of Victoria, B. C.,[87] consists of 905 arc lamps and 1009 five-lamp cluster incandescent-lamp standards. The city is divided into 19 separate lighting circuits each supplied with independent power circuits. The cluster lamp system supplies the central portion of the city. In the western district gas-filled tungsten lamps are replacing the arc lamps.

Cuba.—Many cities in Cuba[88] are installing electric street lighting while other cities are bringing antiquated systems up to date. Havana is providing electric lamps on all streets. Five hundred arc lamps have been replaced by gas-filled incandescent lamps. The old arc-lamp hoods have been adapted as fixtures and bracket arms suspend the lamps over the street in order to get as even a light distribution as possible.

Great Britain.—Automatic lighting and extinguishing of gas street lamps is in operation in over 180 towns of the United Kingdom.[89] As a result of experience gained during the war

[86] *Elec. News* (Can.), April 15, 1921, p. 52.
[87] *Elec. News* (Can.), Feb. 1, 1921, p. 36.
[88] *Elec. Rec.*, Nov., 1920, p. 340.
[89] *Gas Jour.* Sept. 29 1920, p. 674.

London has effected[90] economies in street lighting by the reduction of the lighting hours from 4117 hours per annum to 3940 in the case of electricity and 4024 in respect to the gas lighting. At the same time a considerable number of arc lamps on main thoroughfares have been extinguished at midnight and a reduction has been made in the number of high-pressure gas lamps in the main roads, where such lamps are not on the street refugees or in important positions. In the Westminster district[91] 122 arc lamps have been replaced by 750-watt, 200-volt gas-filled tungsten lamps in lanterns of a special pattern. There are two lanterns on a post, the latter being spaced 160 ft. (48.6 m.) apart, the lamp height being 25 ft. (7.6 m.). The maximum illumination as measured directly under the lamp was 2.6 foot candles and the minimum illumination midway between the lamps was 0.3 foot candle.

The Liverpool city lighting report[92] for 1920 states that during the year the lighting was placed on its pre-war basis. Irrespective of courts and passages, the total length of roads equipped for lighting amounted to 504 miles, of which, 9 miles was by electricity, 490 miles by incandescent gas, 0.5 mile by flat-flame burners, and 4.5 miles by oil lamps.

On the main streets of Taunton, England, the old 7-amp., open type D. C. arc lamps have been completely replaced[93] by 200-watt gas-filled incandescent lamps, with refractor prismatic fittings. Leeds has decided to have three-quarters of the total number of public lamps lighted, which will bring a return to pre-war conditions.[94] Of the 527 gas street lamps in Blythe, Northumberland,[95] 270 are controlled by the two-wave pressure system, the remainder being lighted by hand. The latter require the attention of four men, while the former are looked after by only two. The old mantle burners which were fixed in the main street have been removed and controlled lamps with double burners put in their places. This has greatly increased the light from each lamp. Full street lighting, both gas and electricity,

[90] *Gas Jour.*, Dec. 22, 1920, p. 715.
[91] *Elec.*, Oct. 22, 1920, p. 478.
[92] *Gas Jour.*, April 13, 1921, p. 102.
[93] *Elec. Rev.* (Lond.), May 20, 1921, p. 653.
[94] *Elec. Rev.* (Lond.), Feb. 4, 1921, p. 145.
[95] *Gas Jour.*, Mar. 16, 1921, p. 604.

was resumed[96] in the Dublin metropolitan area during the winter. But in the spring it was decided[97] to shut down the whole of the city lighting from May to October, subject to a possible change in connection with the curfew. The coal situation was said to be responsible for this action.

Paris.—Coal stock reached a point last fall where it was considered feasible to increase[98] the lighting of Paris, France, and 19,000 gas lamps were put in commission and arrangements made for the installation of 1500 electric lamps on boulevards and main streets.

Holland.—The coal shortage in Holland[99] has lead to efforts to conserve gas by the use of electricity, and particularly in street lighting. Amsterdam and The Hague have set the example by adapting the gas street lamps for electricity and in Rotterdam credit was extended to electrify 800 street lanterns.

Italy.—A report of public lighting conditions in Italy states[100] that the enormous increase in the price of coal has practically eliminated gas lighting, while the difficulty of obtaining carbon electrodes and the high cost of labor has hastened the substitution of incandescent lighting for arc lighting. The use of series, gas-filled tungsten lamps is being introduced.

Australia.—The 1919 report of the city of Adelaide, states[101] that provision has been made for the alteration of some 269 inverted-burner gas lamps to the ordinary upright mantle type. During the year the street lighting was curtailed, owing to a coal shortage.

China.—This year has seen the completion of the re-lighting of Shanghai's main thoroughfare, Nanking Road.[102] Thirty-five 400 c. p. cluster fittings have been replaced by seventy-two 600 c. p. gas-filled tungsten lamps. The result is said to compare favorably with the lighting of the principle streets in large occidental cities.

[96] *Gas Jour.*, Dec. 1, 1920, p. 528.
[97] *Gas Jour.*, May 11, 1921, p. 339.
[98] *Gas Jour.*, Oct. 13, 1920, p. 94.
[99] *Elec. Rev.* (Lond.), Sept. 24, 1920, p. 398.
[100] *Elettrotecnica*, Feb. 25, 1921, p. 126.
[101] *Gas Jour.*, Sept. 29, 1920, p. 673.
[102] *Elec. Times*, June 9, 1921, p. 550.

OTHER EXTERIOR ILLUMINATION.

The great development of motion-picture photography has necessitated[103] the provision of auxilliary lighting for out-door work, either to supplement insufficient light in the daytime or to provide for the possibility of night work for locations distant from the studio. For this purpose, special equipment has been designed, a sample set consisting of a compound-wound generator direct-connected to a 6-cylinder water-cooled gasoline engine, the whole mounted on an automobile chassis and provided with cable so that arcs can be operated at a distance. An arrangement of this kind with high intensity arc lamp projectors has been found useful in emergency lighting, such as that required in the case of large fires or building accidents.

The farm-lighting plant which has done so much in recent years to provide light and power to farms isolated from the usual sources of electricity and gas supply, has been introduced[104] into the Far North. A pioneer lighting outfit has been installed in the Kodiak, Baptist Mission on Kodiak Island, just south of Cook Inlet, Alaska. It will undoubtedly do much to mitigate the inconveniences of the long winter nights.

Pre-war high-pressure gas lighting of London's three old corporation bridges, Tower, London and Blackfriars has given[105] place to low-pressure lamps with multiple burners and superheaters in the top of the lanterns. The new Southwork bridge is similarly equipped. It has ninety lamps in groups or clusters of three lanterns mounted on ornamental cast iron standards rising from the parapets and about 45 ft. (13.7 m.) apart. They are placed opposite each other. Each lantern is fitted with a special burner opening out into three nozzles with inverted mantles. By the aid of the super-heater, an illumination of some 250 candles per lamp is obtained.

Sports.—It is interesting tc note the difference in opinion as to the desirability of shadows in lighting installations used for interior and exterior tennis courts. Both uniform and non-uniform systems seem to give satisfaction. Two of the public

[103] *Elec. Jour.*, Feb., 1921, p. 71.
[104] *Elec. Rev.* (U. S.), April 30, 1921, p. 688.
[105] *Gas Jour.*, June 22, 1921, p. 694.

tennis courts of Golden Gate Park, San Francisco, have been equipped with[106] lighting for night-playing as an experiment, which, if successful, will result in a similar installation in the other 18 asphalt courts. The system employed has been in use for some years. Each court has four 1000-watt gas-filled lamps in metal reflectors mounted 30 ft. (9.1 m.) from the ground and suspended over the center line lengthwise on steel cables supported by guyed wooden poles. Players at these courts have said that the gauging of the flight of the ball and timing of strokes were facilitated by the shadows caused by the fixed positions of the overhead lamps. As a contrast to this non-uniform illumination, reference should be made to the lighting of a covered lawn tennis court described under the heading, "Interior Illumination."

Floodlighting.—What is said to be the first floodlighting installation in South Africa has been installed[107] at Pretoria. It illuminates the Executive Capitol, a building 920 ft. (280.1 m.) long and 200 ft. (60.8 m.) wide, which dominates the surrounding country for miles. Thirty-nine projectors, equipped with 1000-watt lamps light up the front and town end of the building. A coloring effect and additional contrasts are provided by some 500-watt lamps in steel reflectors fitted with red glass screens. The result has been so satisfactory that the lighting has been established as a permanent feature and is operated every night. Another so-called initial floodlighting installation, that of a railroad terminal, in Vancouver, B. C., has been reported.[108] Twelve 1000-watt lamps in reflectors placed in the top of ornamental standards in front of the building replace the regular top lamp and globe. An angle reflector with fixed focus and adjustable about 10° is enclosed in a spherical globe of composite nature, the lower half being copper and the upper half of glass. The standards are 27 ft. (8.2 m.) apart and produce 1.5 ft. c. on the face of the building.

As a striking means of indicating its welcome to those attending a convention, the possibilities of fanciful lighting in the street decorations are often employed. This was illustrated[109] in

[106] *Jour. of Elec.*, Nov. 1, 1920, p. 414.
[107] *Elec. Merch.*, Aug., 1920, p. 89.
[108] *Elec. News*, May 15, 1921, p. 49.
[109] *Elec. Rev.* (U. S.), May 14, 1921, p. 767.

Des Moines, Iowa, on the occasion of the meeting of the Council of the Mystic Shrine. The principle features were a large illuminated "Arch of Welcome," and "Arabian Court," and the roofing over of a bridge with festoons of colored lamps, giving it the appearance of a series of tents. At the end of the "Court," a large screen displaying Shrine emblems was illuminated by an 18 inch D. C. arc search-lamp. The "Arch" and the "Court" were decorated with festoons of red, green and yellow 10-watt lamps on 18 in. centres. Throughout the business district the top lamps at street corners were replaced by lamps of larger capacity, 300 or 500-watt, covered by a papier-machee or plaster shell, while the lower lamps were covered with decorative shields. Floodlamps were in use to illuminate the state and court house.

A novel use for floodlighting has been found[110] by a suburban home owner who desired it to illuminate the tops of trees within 100 ft. (30.4 m.) of his house in order, during certain weeks of the year to keep off blackbirds which have roosted in such numbers as to be annoying.

Aircraft.—The proper lighting of aero-dromes, landing fields and air highways continues to demand the attention of those interested in the development of night flying for aircraft. Experiments have been carried[111] out at the Government terminal aerodrome at Droyden, England, and along the route to the Channel Coast with various types of aerial light-houses, search-lights, pyrotechnic lights, and obstruction and landing lights. Illuminated landing "L's" have been fitted out to provide a semi-automatic indicator to aeroplane pilots of the direction and position in which they should land and take off. A new local pilot light at aerodromes consists of a white cone illuminated by light projected downwards and is to be used as the main location light at civil aerodromes, the lighthouses proper being reserved to mark intermediate points along the route.

Sign Lighting.—The temporary suspension of sign lighting during the war period has only served to accentuate the effect produced by the continual increase in this type of advertising.[112] In New York some of the new displays have as many as 3000

[110] *Elec. Contr.-Deal.*, Apr., 1921, p. 251.
[111] *Elec. Rev.* (Lond.), Mar. 25, 1921, p. 392.
[112] *Elec. Merch.*, Sept., 1920, p. 108.

to 4000 of the 75-watt gas-filled lamps, many of them in blue-glass bulbs. It is not merely that there is more sign-lighting but the intensities used have increased, a fact evidenced by the change from 10-watt lamps to 75-watt lamps. Those types of electric signs which have each letter outlined by lamps require,[113] as a rule, a considerable number of units with a consequent high-wattage consumption, to say nothing of replacement expense. In order to remedy this, mirror-disc reflectors have been designed, which, mounted on screw shanks to fit the sockets, replace all but two of the lamps for each letter. The two remaining lamps are fitted with opaque caps to render them invisible from the front of the sign without interfering with light radiated to and reflected from the mirrors.

INTERIOR ILLUMINATION.

Attention has been called[114] to the not-infrequent custom of thinking of the foot-candle illumination as being the all important subject in planning an installation, when the light which reaches the eye is what determines vision and, hence, the reflection factor is a very important element.

In planning illumination for commercial and industrial plants, so many factors have to be taken into consideration, and the standards of lighting change so rapidly that any simplification in methods of computation is sure to be helpful.[115] Constant revision of tables of intensity values suitable for different types of work and classes of service is a valuable aid. Such revision will be found in a discussion of illumination design which also contains a table showing the spacing and mounting height for lighting units, taking into account permissible distance between outlets, and between outlets and side walls as well as the suspension distance for indirect units, from the ceiling to the top of the reflector. A recent discussion of modern domestic lighting[116] in England gives conditions of illumination and foot-candle values for the various rooms of a dwelling house, showing present practice in that country.

[113] *Elec. Rec.*, Jan., 1921, p. 21.
[114] *Elec. Wld.*, Oct. 2, 1920, p. 684.
[115] *Elec. Wld.*, Feb. 19, 1921, p. 421.
Cen. Sta., June, 1921, p. 361.
[116] *Elec.*, Apr. 8, 1921, p. 415.

A Committee of the German I. E. S. has issued[117] a series of recommendations relating to the lighting of interiors. The recommendations include values of lux (Hefner-metre = 0.084 international ft. c.) for various locations, on a working plane 1 m. (3.28 ft.) above the floor, and ranging from 1 lux for areas of relatively small importance to 50 for drawing, embroidery, watch-making and fine mechanical work. When daylight is being exclusively used, the daylight factor (*i. e.*, the ratio between the working daylight illumination and the illumination derived from the unrestricted sky surface) should not be less than 0.5 per cent. Local lamps for individual workers must be so screened that the brightness does not exceed 0.75 candle (Hefner) per sq. cm. For general illumination the brightness must not exceed 5 candles per sq. cm. if the sources are so placed that the line from the eye to the source and the horizontal plane is less than 30°. In other cases these light sources must also be screened or enclosed in light-diffusing globes.

Public Buildings.—The new Town Hall of New York City, a civic auditorium held in trust for the citizens, has been lighted by the indirect system, 2500 lamps being used. After making a careful study of the original fixtures in Independence Hall, Philadelphia,[118] designers have duplicated the chandeliers which were in use at the time of the construction of the building in 1735, and equipped them for electric lighting, frosted glass bulbs at the end of porcelain tubes having replaced the original candles.

The lighting of the new Sessions House of the London County Council[119] gives an indication of present English practice in the lighting of public buildings. The public hall is illuminated by side-wall bronze brackets, each having two arms fitted with spherical globes carrying 100-watt gas-filled tungsten lamps. Pendant ornamenal bronze bowls suspended under the domed roofs and provided with one 1000-watt and three 500-watt gas-filled lamps light the court rooms. The glass-ware of these bowls was especially chosen and has a transmission factor of about 45 per cent. Additional light is given by wall brackets containing

[117] *E. T. Z.*, July 15, 1920, p. 275.
[118] *Elec. Merch.*, Dec., 1920, p. 299.
[119] *Elec. Rev.* (Lond.), Feb. 25, 1921, p. 228.

vacuum tungsten lamps. Illumination tests show 3.8 to 4.2 ft. c. in the court rooms and 4.0 to 5.1 in the public hall. In the offices and committee rooms the illumination varies from 3.1 to 5.7. In the prison cells there is 0.89 ft. c. on a plane three feet from the floor.

A novel method of utilizing properly designed recesses in the ceiling[120] to provide a correct distribution of light from indirect lighting fixtures was adopted in a large western library. So well has the idea been carried out that it is said there are practically no shadows on the floor and the illumination produced is ideal for the purpose for which it is intended.

A survey of one hundred leading hospitals in the vicinity of a large eastern city found only two provided throughout with lighting equipment of the most modern type.[121] Only five had their lobbies and reception rooms lighted satisfactorily and over 14 per cent were illuminated by unshielded incandescent lamps, while 15 per cent had a single gas jet as the only lighting for these rooms.

Assembly Buildings.—The renewal and modernizing of the lighting of an old church is a problem which requires nice discrimination and skill in giving the right kind and amount of illumination without disturbing the architectural effects.[122] The Church of St. Dunstan's at Canterbury was one of the first resting places of pilgrims at the shrine of Thomas á Becket. It has been changed over from gas to electric lighting, the latter accomplished by gas-filled lamps in reflectors giving 2 to 3 ft. c. at an expenditure of 0.3 watts per sq. ft. of floor area.

As a consequence of a change in the gas at Providence, R. I., from a candlepower to a heat standard basis, it was found that 52 per cent of the older public school buildings which had been equipped with flat flame burners had to have a new lighting.[123] After a thorough investigation and some experimenting it was decided to continue the use of gas. The old side-bracket and drop fixtures were made over to carry reflex burners with mica cylinders and opal shades, together with by-pass and pilot accessories. The resultant average illumination on the top of

[120] *Elec. W'ld.*, Apr. 23, 1921, p. 929.
[121] *Elec. Rev.* (U. S.), Apr. 23, 1921, p. 929.
[122] *Elec. Rev.* (Lond.), Nov. 19, 1920, p. 660.
[123] *Am. Gas Eng. Jour.*, Jan. 1, 1921, p. 8.

the desks was 3 ft. c. In London,[124] under the direction of the Elementary Schools Committee of the County Council Educational Commission, experiments have been made in two schools with an improved method of gas lighting. A new form of superheated inverted incandescent burner having a special type of shade was found to give an ample and well-distributed light at a saving in gas consumption and mantle renewal, as well as maintenance.

Hotels.—A considerable use of crystals is to be found[125] in the lighting fixtures of one of the newest of the large hotels in the middle west. Crystal pendants add to the ornate designs of chandelier and bracket fixtures in the promenade. In the main dining room are rows of crystal chandeliers lighted with round frosted bulbs in candle sockets. Similar lamps are used in the lantern-type fixtures suspended from the ceiling of the entrance hall. In the ball room one great crystal chandelier and four smaller ones supply the main illumination, a series of three-lamp brackets being distributed along the wall beneath the balcony. Crystal fixtures are also used in the French breakfast room, the brackets on walls and columns being of glass as well as the chandeliers. Numerous floor and table lamps in the lounge provide a home-like atmosphere, the light being supplemented by just enough from inconspicuous ceiling outlets to provide a moderate general illumination. In the guest rooms are ceiling outlets with ornamental glass-ware, mantle lamps, table lamps, floor and desk lamps. Bell-shaped white glass shades with heavy brass canopies are used in many of the downstairs rooms.

Careful consideration of the specific requirements prefaced the revision[126] of a lighting system in a hotel lobby. Heavy beams finished in a very dark glossy color, and a ceiling in dull tans and yellows made an indirect system impracticable. A lantern type of fixture was found to harmonize with the architecture and a very simple four-sided unit with mitred corners was used. The side panels are approximately 5 in. x 22 in., (12.7 cm. x 55.9 cm.) of dense white opal glass supported in a black iron frame. About one inch from the bottom of the frame a plate of

[124] *Gas Jour.*, May 4, 1921, p. 281.
[125] *Elec. Rev.* (U. S.), May 28, 1921, p. 886.
[126] *Jour. of Elec.*, July 15, 1921, p. 65.

very light diffusing glass serves to conceal the lamp bulb without seriously lowering the amount of light thrown downward. The fixture is designed for either a 200-watt or a 300-watt lamp, and as installed gave an illumination of 4.5 ft. c. on a reading plane with a power consumption of one watt per sq. ft. It is so simple and unobtrusive that, while providing adequate light, it does not distract attention from the huge fireplace and works of art which are the main attractions of the lobby.

Stores.—A study has been made[127] of lighting intensities in twenty-six large department stores located in eastern cities. Readings were taken on either the counter or table level where goods are shown. As a result it has been recommended that in such stores the illumination on the first floor should be from six to ten foot candles, and from four to eight foot candles for other floors.

Factories.—Present practice in factory illumination may be illustrated[128] by the design for a new machine-shop building of concrete. A combination type of lighting was planned, having general lighting for the larger portion of the shop area, with greater intensities along the outside walls next to windows and over benches. The units were arranged, staggered in rows seven feet apart and with a spacing of fourteen feet between units in each row. Where higher intensities were required, the units were spaced seven feet apart on a single line. Standard dome porcelain-enamelled steel reflectors were mounted nine feet above the floor, with 150-watt gas-filled, bowl-enamelled tungsten lamps. The system was designed to give an average resultant illumination on the working plane of about nine foot candles, assuming a utilization factor of 50 per cent.

Shop lighting practice in England[129] may be seen in the installation at a motor repair works. General lighting in the power station is produced by two rows of six 300-watt gas-filled lamps in reflectors mounted 21 ft. (6.4 m.) above the floor. The foot-candle values exceed four and the power consumption is approximately 0.65 watts per sq. ft. In the unit and erecting shop the lamps are hung 24 ft. (7.4 m.) from the floor. In the machine shops, 11 and 16 ft. (3.3 m. to 5 m.) heights are found,

[127] *Elec. Rev.* (U. S.), Feb. 12, 1921, p. 251.
[128] *Elec. Rev.* (U. S.), Feb. 5, 1921, p. 213.
[129] *Ill. Eng.* (Lond.), Oct.-Dec., 1920, p. 287.

varying with the nature of the work, the illuminations being around 3 ft. candles over gangways and 7 ft. candles over lathes and machines.

Open-back inclinable punch presses in machine shops are frequently provided with localized lighting by an incandescent lamp hung behind the die in the open back, or by a drop lamp over the operator. One shop has improved[130] on this by using a bracket made of standard parts, such as a flexible goose-neck, brass hickey and a small reflector made for use on a portable lamp around automobiles. The reflector is 2½ in. (6.4 cm.) in diameter and completely shades the bulb, which is an ordinary 6-8 volt, 4 c. p. automobile lamp. Current is obtained from a 110-volt, A. C. line, through a toy transformer which takes care of six or more lamps. Several hundred of these brackets have been installed on presses in the shop in question.

Where detail is so important as in the making of small and odd-shaped cores of dark sand, the lighting[131] of the core room of a foundry presents a problem a little out of the ordinary. Such a room recently equipped has a concrete floor 60 ft. x 70 ft. (18.2 m. x 21.3 m.). Thirty-two core-makers' benches arranged four in a row are placed by the windows on one side. Over each section of eight benches are placed two 100-watt, gas-filled lamps in 15 in. (0.4 m.) steel-dome reflectors, 10 ft. (3 m.) apart. They are 10 ft. (3 m.) from the floor and give an illumination of 4 ft. c. on the work benches. Large cores made on the other side of the room are lighted by means of three 100-watt lamps suspended from a messenger wire and are 10 ft. (3 m.) from the floor, having steel reflectors and pendant switches. Five 100-watt lamps, 12 ft. (3.6 m.) from the floor light the core pilers along the centre of the room. 25-watt lamps in key sockets light the core racks, the coal-heated oven, the fire pit and the wire machine.

In putting a new lighting system in a saw mill it was found[132] possible to get an intensity of 6 ft. c. at an expenditure of only 0.7 watts per sq. ft. In the main shop, 66 ft. x 125 ft. (20 m. x 38 m.), where many circular saws, band saws and

[130] *Elec. W'ld.*, Mar. 19, 1921, p. 657.
[131] *Elec. W'ld.*, Apr. 16, 1921, p. 884.
[132] *Elec. Times*, Mar. 31, 1921, p. 314.

planing mills are in operation, the lighting equipment consists of fifty-eight 100-watt gas-filled lamps with intensive reflectors uniformly spaced over the area and at a height of 10 ft. In the carpenter shop with the same type of reflectors and lamps, 6 ft. c. were obtained with only 0.65 watts per sq. ft.

In the sewing-machine room of a women's suit factory[133] the lighting system consisted of a number of 100-watt clear-bulb gas-filled lamps in reflectors hung promiscuously about the room, while individual machines were given localized lighting by 40 or 60-watt clear bulb vacuum lamps in tin reflectors. This system has been replaced by a new overhead equipment of 150-watt bowl-enamelled lamps in standard dome reflectors on approximately 10 ft. x 10 ft. (3 m. x 3 m.) centres, 10 ft. (3 m.) from the floor, giving an illumination of 9 ft. c. Each machine is provided with a deep bowl reflector mounted on an adjustable arm and carrying a 15-watt clear-bulb vacuum lamp which gives 40 ft. c. at the point of the needle. The result has been a decided improvement in the appearance of the room and in the amount of work turned out.

Additional information on the relation between lighting and factory output[134] is to be found in a report (Bull. No. 9) issued by the Industrial Fatigue Research Board of Great Britain. The report deals with conditions in two mills investigated and the following conclusions were reached: (1) There is a gradual increase in the output of silk weavers during the time from Dec. to March, due chiefly to the gradual decrease in time during which artificial lighting is necessary; (2) that under artificial illumination production falls off by about 10 per cent of the daylight value of the output. It might be added that illumination at the cloth fell, in the one mill varied from 3 to 3.5 ft. c. and on the porry from 3 to 5 ft. c. In the other mill, each loom was provided with two 30-watt lamps, the control of these lamps being in the hands of the operators. The two methods of estimating output as an indication of influence of fatigue were based on the number of picks made by a loom in a given period, and the time taken to weave a given area of cloth.

[133] *Elec. Wld.*, May 7, 1921, p. 1054.
[134] *Ill. Eng.* (Lond.), Sept., 1920, p. 245.

An English shoe factory[135] which is lighted by gas, has in one of the finishing rooms special localized illumination of 14 ft. c. at the points of the needles, while the fitters' tables have from 12 to 16 ft. c. Low pressure burners with aluminum- covered reflectors are located 1 ft. 9 in. (0.53 m.) above the needles and 2 ft. 6 in. (0.76 m.) above the work on the fitters' table.

The presence of steam vapor carrying dirt and bleaching chemicals complicates the problem of providing suitable lighting in a laundry. A recent installation[136] comprised prismatic reflector units of the "reflector-refractor" type mounted 10 ft. (3 m.) from the floor on 19 ft. (5.8 m.) centers and containing 200-watt gas-filled tungsten lamps, in the washing, ironing, drying, and pressing departments. In the sorting, marking and packing rooms the same unit, with a smaller wattage lamp, lower mounting heights and closer spacing distances, was employed. After two months' use the foot-candle illumination in the washing and drying rooms was found to be 3 ft. c., and in the other departments 5 ft. c. In the offices larger units were used and gave 8 ft. c illumination.

To keep lighting equipment clean seems to be enough of a problem in ordinary commercial installations, but it becomes an especially serious question where the atmosphere is very heavily dust-laden as in flour mills, grain elevators, coal mines, et. cetera. The lighting of the coal-grinding plant of a cement mill presents this type of problem. In one case[137] it has been solved through a realization, as the result of experiment, that by preventing air currents around the lamp, dust accumulation can be prevented. Deep-bowl one-piece standard enamelled reflectors were found satisfactory. An air pocket of dead air is formed which keeps out the dust-laden air.

Transportation.—An interesting case of specialized lighting[138] is to be found in the illumination of the escalator of one of the London tube terminals. Two diffusing glass bowls containing respectively three 100-watt and three 300-watt gas-filled lamps produce a fairly uniform effect. The difference in the wattage compensates for the difference in distance from the

[135] *Ill. Eng.* (Lond.), Oct.-Dec., 1920, p. 293.
[136] *Elec. Rev.* (U. S.), Apr. 9, 1921, p. 578.
[137] *Elec. Wld.*, Apr. 2, 1921, p. 768.
[138] *Ill. Eng.* (Lond.), Oct.-Dec., 1920, p. 270.

treads to the ceiling at the top and bottom of the stairs. There is also an emergency series of three lamps on a separate circuit in the top bowl, to provide for possible failure of the regular lighting. The bowls are mounted below a white surface giving a good diffusion, which is augumented by the white-tiled side walls.

As a result[139] of tests made on a standard 70-ft. (21.3 m.) day-coach equipped with ten center-deck lighting units and a similar baggage car with eight units, the Commission on Illumination of the American Railway Electric Engineers has recommended a change from the 50-watt vacuum tungsten lamp to the same wattage gas-filled lamp. It should be used, however, only with a deep bowl or other type of reflector that will very largely cut off the direct rays of light from the line of vision of passengers.

In a discussion on train lighting before the German Illuminating Engineering Society[140] it was found that 98 per cent of all gas lighting in trains is on the Pintsch system, while 2 per cent is acteylene. The standard gas lamps have an intensity between 20 and 80 H. K. with a power consumption of 2.4 "W. E." per hk. hour. Electric lighting is partly through accumulators and partly through dynamos on the car axles.

A new system has been developed[141] for the lighting of railroad engine houses. The features of the system are a special type of reflector and the method of mounting these reflectors in pairs so that the beams of light from each pair are crossed. The units have a cast iron body with a reflector made of glass which has a surface like that of sheet metal which has been hammered with a ball-peen hammer. This produces many small reflectors and results in a distribution of light rather than glare. It is readily cleaned and not affected by smoke from the engines. In one installation the units are mounted 10 ft. (3 m.) from the floor, and generally 7½ ft (2.3 m.) each side of the centre of the track. The lamps are 100-watt gas-filled tungsten. In another case a 13½ ft. (4.1 m.) height is used.

Theatres.—In connection with the constantly increasing number of theatres being built for moving pictures there has been

[139] *Rlwy. Elec. Eng.*, Oct., 1920, p. 371.
[140] *E. T. Z.*, Apr. 21, 1921, p. 409.
[141] *Rlwy. Elec. Eng.*, May, 1921, pp. 179, 183.

concurrent progress in the more or less special lighting suitable[142] for such places of amusement. In general, three systems of illumination are provided, direct lighting from chandeliers, generally of a highly decorative character,—indirect lighting,—in many cases through coves, and a colored lighting system having three or four tints. Translucent glass ceiling inserts concealing lamps of various colors are growing in favor.

A study[143] of illumination conditions in moving picture theatres brought out the result "that illumination on the table plane of from 0.1 to 0.2 ft. c. may be used without interfering with the quality of the projected picture and further, to avoid glare and undue lowering of the adaptation level that the maximum surface brightness that may fall within the field of vision of the observer should not exceed 2.5 to 3.0 milli-lamberts."

In one of the newest and most expensive theatres for moving picture entertainment the vestibule is lighted by two metal cluster lamps hanging from the ceiling.[144] The lobby is illuminated by three large crystal chandeliers and fourteen cluster bracket lamps, as well as by a cove-lighting system running around the ceiling. In the foyer, suspended from a chain, hangs a massive crystal chandelier fitted with white and amber lamps, while four cluster brackets give added illumination. The main auditorium measures 109 ft. x 160 ft. (33.1 m. x 48.6 m.). In the ceiling under the balcony are three inverted bowl lamps and cove-lighting, the latter being also used for the balconies themselves. The auditoriumm lighting is in yellow, red and blue, while that of the stage is the same with the addition of white.

The foyer of a new middle west moving-picture theatre, designed after Chapelle of Versailles, is 25 ft. (7.6 m.) wide, 125 ft. (38 m.) long and 70 ft. (21.3 m.) high and has its main lighting furnished[145] by four crystal chandeliers, each equipped with electric candles. Additional illumination is furnished by torcheres in each corner with cluster candles, and by sconces of gold-plate finish bearing shields to prevent the bare lamps from being reflected in the mirrors. In the main auditorium is a sunburst dome 65 ft. in diameter, silver lined and lighted by lavender-colored

[142] *Mov. Pic. Wld.*, Apr. 30, 1921, p. 939.
[143] *Month Abs. Bul.* Eastman Kodak Co., Sept., 1920, p. 293.
[144] *Mov. Pic. Wld.*, July 23, 1921, p. 450.
[145] *Mov. Pic. Wld.*, Mar. 12, 1921, p. 147.

lamps. All lighting projections and flood-lamps are concealed behind pastel ornaments, while the stage has 150 spot lamps and the orchestra pit 15 stage lamps. Three separate means of illumination are provided for the theatre as a whole so that in case of failure of the main system, two others are available for emergency use.

The auditorium of what is said to be the largest theatre in the world is lighted[146] by lamps concealed in coves, having three colors available, canary, red and blue, and by chandeliers and wall clusters largely equipped with amber-colored lamps. A dome in the ceiling has a combination of cove lighting and that from a large crystal chandelier. Spotlights projected through the crystals onto the stage produce peculiar shadow effects. The main floor under the balcony has panel lighting giving a skylight effect through recesses in the ceiling containing colored lamps and concealed by glass. The stage has four sources of light available, namely, foot-lamps, border lamps, spot-lamps, and flood-lamps. 1000-watt floodlighting units are placed above, behind and in the wings of the stage and use colored screens as desired. There are in regular use more than 17,000 lamps of various sizes from 10-watt sign lamps up to the 1000-watt units. One of the largest fixtures for indirect illumination ever built has been installed[147] in a middle west theatre. It is 15 ft. (4.6 m.) in diameter and contains 118 lamps, the main bowl carrying one hundred 200-watt bulbs in reflectors, while the lower bowl has eighteen 60-watt lamps, the latter used to light the exterior of the large bowl and serve in cases of emergency. Special arrangements were provided for cleaning. In the main bowl, colored cover glasses over the reflectors provide four groups of 25 lamps each of red, blue, amber and white. The proscenium arch of the theatre is lighted by twelve 1000-watt lamps.

In Pittsburgh orders have been issued[148] to theatres, picture houses, hotels, and rooming houses to install auxiliary gas lamps at exits to the street and at doors and windows leading to fire escapes. In accordance with recommendations of the National Underwriters' bodies, all gas lamps near fire exits will be enclosed in green instead of red globes, as was formerly the

[146] *Elec. Wld.*, Oct. 16, 1921, p. 777.
[147] *Elec. News* (Can.), Apr. 15, 1921, p. 51.
[148] *Mov. Pic. Wld.*, May 14, 1921, p. 154.

case. The change has been suggested because red is looked on as a sign of danger, while green denotes an avenue of safety.

A method of eliminating the necessity of foot lamps to illuminate the front of the stage in theatres, is reported[149] from Germany. Two large reflectors totally enclosed, with a lens in front of only 15 cm. diameter are placed high up in the fore part of the stage, one fixed on each side. A dimming arrangement and various colors are provided and the system is said to give satisfactory use in a German theatre.

Studio Lighting.—In the early days of moving pictures, daylight was the principal requisite for indoor, as well as outdoor photography. But as the industry grew, there has been a gradual change until now artificial light is used almost exclusively in American studios for all interior scenes. The light sources employed range from "baby" arcs, medium carbon arcs, big arcs with double carbons, high intensity impregnated carbon arcs, to mercury vapor arcs in single or multiple units. A device is now under development whereby it will be possible to cut the intensity of a big arc or spot-lamp from full to zero light or the reverse without changing the spread of the beam. Development work is also going on in the incandescent lamp field.[150]

The elaborate and powerful lighting units which have been such factors in the great expansion of the moving-picture industry have been adopted[151] and adapted by the commercial photographers. To-day little retouching is done on a properly lighted photograph, as almost any effect can be obtained through the proper use of lights.

Sports.—Reference has been made, under the heading "Exterior Illumination" to the lighting of outdoor tennis courts. A covered lawn tennis court, comprising two courts side by side covering 80 ft. by 120 ft., (24.3 m. x 36.5 m.) in a building having a height from floor to tie beams of 20 ft. (6.1 m.) has been successfully lighted,[152] in spite of the fact that the floor and walls are finished dead black. This was done to furnish contrast with the white halls. A direct-lighting system was decided upon and 500-watt gas-filled lamps in steel reflectors were arranged along

[149] *Tech. Rev.*, May 17, 1921, p. 110.
[150] *Sci. Amer.*, Feb. 19, 1921, p. 148.
[151] *Printer's Ink Monthly*, Mar., 1921, p. 16.
[152] *Elec. Rev.* (Lond.), Nov. 12, 1920, p. 618.

the sides of each court at a height of 18 ft. (5.5 m.). The maximum illumination was found to be 3.4 ft. c. and the minimum 3 ft. c., showing a very uniform illumination. Another illustration of illumination for indoor sports is that of racket courts in Montreal.[153] The room is 60 ft. (18.2 m.) long by 30 ft. (9.1 m.) wide and about 30 ft. (9.1 m.) high, daylight being admitted through a window in the roof. There are three rows of 25 reflectors. The front row is suspended 13 ft. (4 m.) from the front wall, 30 ft. (9.1 m.) from the floor, six equipped with 200-watt and the rest with 100-watt lamps. The back row has ten 200-watt and the rest 100-watt, suspended 3 ft. (0.91 m.) in front of the back wall and 23 ft. (7 m.) from the floor. The middle row is 35 ft. (10.6 m.) from the front wall and has the same equipment as the front row. In addition, there are two floodlighting projector units, one suspended over each of the rear corners of the court and 23 ft. (7 m.) from the floor. Wire guards are provided for all units. The illumination increases gradually from about 10 ft. c. in the front of the court to as high as 25 ft. c. in the two rear corners, on a plane 2 ft. 6 in. (0.76 m.) from the floor. Shadows are practically eliminated and a pencil standing vertically on the floor of the court throws no perceptible shadow. The total connected load gives 5.61 watts per sq. ft. of floor area.

FIXTURES.

While there have been considerable developments in globes, shades and reflectors in the United States, similar developments have been going on in Germany, as is evidenced[154] by the numerous patents taken out in that country. In considering the subject of fixtures it is natural to turn to the Annual Convention[155] of the Lighting Fixture Manufacturers, Dealers and Glassware Guild. Apparently there has been little change in the tendency to use candelabra effects, with or without shades, and the use of exposed round-bulb lamps for residential and hotel fixtures. This tendency was noted in last year's report.[156] Crystals and prisms are popular,[157] especially in moving-picture theatres. Color and decorative effects predominate and many new finishes for metals

[153] *Elec. News*, Dec. 1, 1920, p. 40.
[154] *Elek. Anz.*, May 11, 1921, p. 467.
[155] *Elec. Merch.*, Feb., 1921, p. 62.
[156] *Trans. I. E. S.*, Oct., 1920, p. 463.
[157] *Elec. Wld.*, Apr. 30, 1921, p. 1019.

have been made available to match the color tones of individual rooms. Colored-pattern vase effects are being worked into the fixture proper, and there are also colored flowers and drops attached or hung here and there. Sometimes these are of glass. sometimes of metal.

The National Council of The Lighting Fixture Manufacturers[158] has been investigating the question of standardization of mechanical details of lighting fixtures and a system has been proposed covering a complete set of gauges and templets for every detail of glassware, heels, globe proportions, lamp positions, etc. Manufacturers have also been standardizing their products[159] as a whole ever since the war. Many who made hundreds of designs have concentrated on a few. In one case a company discontinued 16,000 difference patterns it had been manufacturing and is focusing its entire attention on one design. Another company has less than fifty per cent of the designs it had four or five years ago. Still another company has cut down from 600 to 250 patterns. In addition to styles much has been done to reduce the number of sizes and to use as few as possible consistent with the standard lamps now in existence.

In line with the development of units which can be hung by the householder, is a big advance[160] in the design of attachment plugs and receptacles for lighting fixtures. It eliminates the soldering connections. Eleven manufacturers have agreed on a standardized set of models for the production of a single unit for the electrical and mechanical connections in the attaching and hanging of both side-wall and ceiling fixtures. A modification of this detachable fixture idea,[161] has been suggested for industrial units in order to facilitate cleaning and lamp replacement. An effort[162] is being made to get a more suitable name than "fixture" for this new type of movable unit. The standard plug and receptacle for these units will be known as "elexits."[163] Under the caption, "Interior Illumination" will be found a description of what is said to be the largest indirect lighting fixture ever built.[164]

[158]*Elec. Wld.*, May 7, 1921, p. 1074.
[159]*Elec. Rec.*, Sept., 1920, p. 165.
[160]*Elec. Wld.*, July 9, 1921, p. 91.
[161]*Elec. Wld.*, Apr. 9, 1921, p. 533.
[162]*Elec. Wld.*, Apr. 23, 1921, p. 937.
[163]*Elec. Rev.* (U. S.), July 23, 1921, p. 133.
[164]*Pop. Mech.*, July, 1921, p. 18.

Reflectors.—There is a general tendency in the design of store and office fixtures[165] to make the units dust-proof as far as the interiors are concerned. This greatly simplifies the cleaning problem. Among the samples of this type of lighting fixture is one made in three sizes, 11 in., 14 in., and 16 in. (28, 36, 41 m.), fitted either with a keyless or pull-chain socket and with an ornamental globe of pale brown toning, with classical etching, and a bottom rosette and tassel. Another[166] has a globe with a flat wide top to give a softly diffusing light on the ceiling, a side surface in conical form, with low intrinsic brilliancy, to light the walls, an angular inward under portion to help distribute light over the working planes in a wide area, and a convex center or bull's eye in the under part to concentrate light on the working plane. It is also made in four sizes and may be obtained in decorative form for home use.

A feature of a new indirect unit[167] which emits only fourteen per cent of the lamp output below the horizontal, is the use of two-inverted bowls, one inside the other with different optical properties, for the purpose of producing a fading spot on the ceiling. Heretofore, indirect lighting units have in general produced a comparatively narrow, well-marked spot. The new unit throws a wide spot that shades away with no marked limit even when mounted only 12 in. below the ceiling. The outer bowl is translucent and thus avoids a sharp contrast as seen against the ceiling. All glass surfaces exposed to the air are smooth, making cleaning easy. The space between the two bowls is sealed at the top by a white enamelled diaphragm. Another innovation is the use of silk and similar fine-mesh materials, which may be placed around the inner reflector in the form of an outside cover. Parchment and silk shades may also be used with this unit for home lighting.

Six separate and distinct designs to fit conditions required for various locations, such as stores, schools, churches, etc., may be made by rearrangement of the parts of a single lighting unit.[168] The parts are made of heavy solid spun copper and there is an

[165] *Elec. Rec.*, July, 1921, p. 20.
[166] *Elec. Rev.* (U. S.), Apr. 9, 1921, p. 594.
[167] *Elec. Rev.* (U. S.), Apr. 9, 1921, p. 594.
[168] *Elec. Merch.*, Dec., 1920, p. 326.

interchangeable fitter for either of two sizes of glass or metal reflector. It is said to be dust and insect-proof. A new unit[169] planned for store and factory lighting has a focusing arrangement by means of which the lower part of the two-piece reflector may be raised, lowered or tilted, thereby altering the light distribution throughout a considerable range. A globe designed[170] for gas-filled lamps of not over 200-watt capacity has a thin skin of a special opal glass to produce diffusion, mounted on crystal glass to give the needed rigidity and strength.

More evidence of the effort to produce dust-proof units is to be found[171] in a semi-indirect commercial lighting reflector which has a glass globe blown in one piece and enamelled on the sides and bottom. It is claimed that light diffusion is obtained equal to the best heavy density glass bowls with a resultant low intrinsic brilliancy. Since the exterior surface is all smooth glass dust may be readily removed. The lamp can be taken out or replaced without disturbing the globe itself and with the socket is easily accessible through the removal of the bottom cap.

In spite of the growing tendency to develop one-piece dust-tight globes and reflectors for stores, factories, offices, et cetera, the two-piece units seem to maintain their popularity and new designs continue to appear.[172] In some the upper reflector is of the inverted shallow-bowl type, in others the inverted frustrum of a cone, while the lower enclosing member may be almost spherical, or acorn-shaped or a combination of a shallow bowl with an inverted bowl. In one case[173] the lower member is merely a porcelain-enamelled metal shade which fits around the lamp bulb and redirects the horizontal light. The materials range from "alabaster-cased" glass, "radiant" glass, and opaque glass, to porcelain and composition.

Fixtures of three different types[174] have been designed for heavy duty under conditions where gases, vapors, dusts, or explosive or inflammable materials are apt to accumulate. They are sealed against the entrance of foreign material at the conduit

[169] *Elec. Rec.*, Sept., 1920, p. 172.
[170] *Elec. Rec.*, Nov., 1920, p. 512.
[171] *Elec. Rev.* (U. S.), Jan. 15, 1921, p. 114.
[172] *Elec. Rec.*, Feb., 1921, pp. 98, 99, 101.
[173] *Elec. Merch.*, Feb., 1921, p. 110.
[174] *Elec. Rec.*, July, 1921, p. 20.

and at the globe. The lamp bulb is enclosed in a vapor-proof globe and the reflector is of porcelain-enamelled steel not affected by fumes or gases. Glass filters may be used to give daylight values. Arrangements are made for easy cleaning.

Fixtures for Special Purposes.—It is often a critical matter[175] in surgical operations for the operator to have difficulty in seeing, due to shadows cast by his hands or instruments. A lighting unit especially designed to obviate this difficulty has a gas-filled tungsten lamp placed in a cylindrical lens cell of the same design as the lenses of the usual mariner's lights. The lens system projects the light rays sideways to a set of fifty mirrors arranged as sectors around the inside of a large metal bowl reflector. The mirrors are tilted at such an angle as to throw the reflecting beams downward, thus forming a concentrated circle of light. The area of this circle can be altered by varying the distance between the light source and the surface on which the rays are centered. On board ship, in order to concentrate enough light to illuminate the compass or clock without an excess which would hamper the captain's ability to see, a special lamp[176] is made with a shield as small as possible, and a bulb run at half voltage. It may also be used for a tiller light.

Color effects in show-window lighting may be produced[177] by a method which uses colored gelatin in place of colored glass formerly used, and which had a tendency to break as the result of the heat from the lamps. A metal frame which fits over the opening of the reflector supports a slide which carries the film, the latter being held in place by fine steel meshes. The slide slips in the frame, enabling the color to be readily changed. The gelatin used is not inflammable and is claimed to hold its colors without fading. The method has been adapted to all-glass show-window reflectors.[178] For stage lighting a floodlighting unit has been worked out consisting[179] of a box, 40x20x8 in., (100x50x20 cm.) containing gas-filled tungsten lamps consuming a total of 3,000 watts, which may be dimmed without the use of rheostats and without change in color, remaining white in full dimming in-

[175] *Sci. Amer.*, Apr. 23, 1921, p. 234.
[176] *Elec. Merch.*, Aug., 1920, p. 101.
[177] *Signs of the Times*, Sept., 1920, p. 18.
[178] *Elec. Rec.*, June, 1921, p. 376.
[179] *A. E. G., Mitteilungen*, Oct., 1920, *Tech. Rev.*, Feb. 8, 1921, p. 146.

stead of turning to a reddish yellow. The primary colors are contained in the apparatus and any primary or intermediate tint can be obtained separately dimmed. There are no lenses or reflectors and the unit is operated at any angle and controlled from any convenient location by means of wires. A novel method of producing[180] color effects with a stereopticon involves the use of a water cell 1.25 in. (3 cm.) thick, with mica sides, which is fitted in front of the slide carrier and connected by tubes to a series of cans above containing water of various colors. A keyboard permits the operator to inject at will fine streams of any desired color into the cell. The slide is changed when the cell has received enough color to obscure the image. The cell is then drained giving on the screen, through the lens reversal, the effect of a rising curtain.

Residential.—A new dining-room fixture[181] embodies the idea of the old dome and eliminates some of its objections. The source is set high in the shade so that direct rays do not strike the eyes of a person sitting at the table. The glass shade is slightly conical and ornamented. The holder supports it from the inside. Among the novelties[182] in reading lamps may be mentioned two in which dolls form the main support, the lamp socket being in the head and fitted with a silk shade. The artificial daylight unit of the reflecting type devised in England has been adapted[183] for table-lamp use.

Highway Lighting.—In order to save the loss of light by absorption in a diffusing globe,[184] a new globeless standard has been developed for street lighting. The main feature of the fixture is the porcelain insulator which is made flaring and thus serves also as a reflector and socket holder. It is designed to redistribute downward the light coming upward from the lamp. Glare is eliminated by using bowl-frosted lamps which can be seen only against the white porcelain of the insulator as a background.

Perhaps the most striking development in fixtures for highway lighting is a new unit[185] made double and fixed so that it

[180]*Pop. Mech.*, May, 1921, p. 711.
[181]*Elec. Rev.* (U. S.), Sept. 11, 1920, p. 423.
[182]*Elec. Rec.*, May, 1921, p. 309.
[183]*Elec. Rev.* (Lond.), Feb. 18, 1921, p. 108.
[184]*Elec. Wld.*, June 18, 1921, p. 1430; also,
Report of Lighting Sales Bureau, N. E. L. A., May, 1921.
[185]*G. E. Rev.*, Jan., 1921, p. 49.

utilizes the light from a single lamp bulb placed in between, which thus illuminates the road in both directions. It has three reflectors,[186] one within the other, somewhat like a nest, arranged so that a very large part of the light ordinarily not useful is thrown on the road surface, the rays making an angle of 10° below the horizontal, giving the same effect as an overhead reflector 15 ft. (4.6 m.) in diameter. The bracket holding the reflector is adjustable in both vertical and horizontal directions so that the fixture can be mounted on a pole close to the road or several feet back of it. A test installation has been in operation where 250 c. p. lamps are used at a height of 30 ft. (9.1 m.) and at 400 ft. to 600 ft. (121.6 m. to 182.4 m.) intervals.

Another radical departure[187] in the design of fixtures for street lighting has been made in England. One unit as described consists of a canopy holding a clear glass globe hexagonal in shape with narrow joints. Under the roof is a 10 in. special reflector in the center of which is a gas-filled tungsten lamp. The bulb of the lamp fits with ample clearance into the top of an inverted V-shaped mirror. The slope of the inverted V and its nearness to the bulb can be adjusted. Both reflectors and mirrors are made of glass silvered and coppered. When the lamp is in position the sides of the inverted V face up and down the street. The lamp gives direct lighting immediately below the fixture and the position of the mirrors is such that they throw no appreciable shadow. The silvered glass surfaces being flat are easily kept clean. Tests on a fitting designed for a 30 ft. (9.1 m.) street and carrying a 300-watt lamp gave 5000 to 7500 c. p. in directions within 15° of the horizontal. The illumination on the road at distances from 20 to 90 ft., (6 m. to 27.3 m.) with the lamp 24 ft. (7.3 m.) high varied between 0.3 and 0.4 ft. c.

A special feature of a bracket boulevard standard for street lighting using series incandescent lamps is the provision[188] of a small 15-watt, 60-volt lamp behind a colored bull's eye in the post about 5 ft. (1.5 m.) from the ground. If the main lamp in the lantern burns out, this signal lamp, which is ordinarily dark, automatically lights up the bull's eye to serve as a sign of the

[186] *Pub. Wks.*, Apr. 16, 1921, p. 322.
[187] *Elec. Times*, Dec. 2, 1920, p. 427.
[188] Report of Lighting Sales Bureau, N. E. L. A., May, 1921.

burnout location. The result is secured by taking advantage of the characteristic open circuit rise in voltage of the 20-amp. series transformer which supplies the 600-c. p. lamp.

Special fittings have been developed[189] for locomotive tenders, both for regular and emergency work. One for regular work has a case of cast non-corrosive metal with a hinged door at the bottom containing a plate-glass window, through which light reflected from mirrors inside the case is thrown down to illuminate couplers and steps.

Photographic Studios.—A new reflector is especially designed for spread and spot-lighting in photographic studio work.[190] It is formed of selected glass accurately bent to the curves worked out to give the required effect, and coated with successive layers of silver protected by electrically deposited copper. It is used in conjunction with a high-powered gas-filled tungsten lamp. An adjustable standard[191] to hold lamps in a photographic studio is a mechanical duplication of the human arm from the shoulder to the wrist. A tripod base carries an adjustable centre rod from which extend two friction-jointed arms supporting two electric lamps with their reflectors. Each of the two arms has three friction disk joints.

Materials.—The use of Italian alabaster of the pure white and grey-veined varieties for lighting purposes continues in England.[192] Vitreosil has for some time[193] been used for inner cylinders and globes of gas lamps. It is now available in the form of lighting bowls in which it is possible to have high-powered mantle clusters entirely concealed without the risk of fracture under extreme temperature conditions. Vitreosil semi-indirect bowls have an inner surface of naturally pearly lustre, giving a diffusely reflected light.

Concrete has been used for some time as a material for street lamp standards, and it has now been adapted[194] for floor lamps to be used in sun porches, sleeping porches or other places where the

[189] *Ry. Elec. Eng.*, Feb., 1921, p. 93.
[190] *Elec. Times*, June 30, 1921, p. 634.
[191] *Elec. Rec.*, Jan., 1921, p. 13.
[192] *Elec. Rev.*, (Lond.), Mar. 25, 1921, p. 375.
[193] *Gas Age*, Apr. 25, 1921, p. 351.
[194] *Illus. Wld.*, Apr., 1921, p. 275.

weather is a disturbing element. Such lamps are equipped with parchment shades which are washable and so firmly attached that they cannot be blown off.

Brackets.—The possibility of multiple movement[195] has been applied to various types of portable and bracket types of lamps in Germany. One of these adjustable wall brackets[196] consists of a round bar fitted in two brackets, and installed vertically. On it slides a latticed frame, to one end of which is attached an extension rod which is provided with another rod arranged to be rotated about the first rod as an axis. To the second rod the lamp and shade are fastened. A wide variety of movements is thus available. Another adjustable[197] fixture has been produced by a French designer, but is intended to be fastened to the ceiling. It has a telescoping arm attached to a swivel-fitting at the ceiling and carries a drop lamp, which may thus be moved to different heights and over a considerable area.

Globe-Holders.—Additional developments have been made in Germany[198] in globe-holders, which eliminate the use of the old three-screw arrangement and which were referred to in last year's Report. One new type has only two arms made of spring material and holding two pieces which fit around the neck of the globe. By pulling out either arm the bowl may be inserted and the tension of the arm will hold it firmly. Another type has three tension arms supporting a coiled spring which encircles the neck of the globe. Still another method[199] of getting away from the three or four-screw method of holding globes and reflectors is through the use of two curved shoes which fit around the inside of the neck of the globe and by surface contact clamp it to the rim of the holder. The shoes are forced outward by turning a knurled screw, and being of the same material as the fixture, are subject to the same expansion and, hence, are free from unequal stresses due to heating.

In order to replace the rings ordinarily employed to support the bowls of chain fixtures,[200] a combined hook and clip has been

[195] *Helios,* Mar. 6, 1921, p. 933.
[196] *Helios,* Apr. 3, 1921, p. 1343.
[197] *Pop. Mech.,* July, 1920, p. 105.
[198] *Helios,* Oct. 17, 1921, p. 3919.
[199] *Elec. Cont.-Dealer,* July, 1921, p. 391.
[200] *Elec. Rev.* (U. S.), Feb. 18, 1921, p. 223.

brought out which is the more effective the heavier the bowl. It consists of a bent lever of cast brass, the top part of which is hooked for the reception of the chain, while the other end fits against the inside of the bowl.

Accessories.—To eliminate the shadows of the chains and edge of the bowl in indirect or semi-indirect units,[201] a shadow shield has been designed to slip over and cover the neck and upper part of the bulb of the lamp used. The shield is of white translucent glass. A special canopy has been developed to permit the proper adjustment of gas-filled lamps in reflectors.[202] It is fitted with a three-arm spider which screws up and down on a center rod carrying the suspension hook and lamp-holder. The arms of the spider are slotted, each slot carrying a roller over which passes the chain supporting the gallery of the reflector.

The use of an anti-vibration disk,[203] intended to protect incandescent lamp filaments from breakage through shocks has been extended, in England, to ship fittings. The disk is made of two concentric rings connected together by strips of phosphor-bronze gauze cut on the bias. In practice, two of the disks are used, rigidly connected together.

Devices to prevent stealing of incandescent lamps have been worked out in Germany.[204] One employs a winding of insulating material which encircles the lamp base and has three small screws, which, when tightened prevent the removal of the lamp until they have been unscrewed. In this country[205] a new locking device makes use of a coiled spring which is screwed into the socket after the lower shell has been removed. The shell is then replaced. The bulb must be broken to free the lamp.

The use of the gas-filled lamp in sign lighting has brought about considerable breakage in stormy weather, due to sudden chilling of the bulbs by rain or sun. To obviate this trouble[206] sheet-metal spoon-shaped caps have been designed to fit snugly over the exposed part of the bulb and protect the hottest spot, which is just over the filament.

[201] *Elec. Merch.*, Aug., 1920, p. 100.
[202] *Ill. Eng.* (Lond.), Jan., 1921, p. 26.
[203] *Elec. Rev.*, (Lond.), Mar. 4, 1921, p. 293.
[204] *E. T. Z.*, Feb. 10, 1921, p. 136.
[205] *Elec. Rec.*, May, 1921, p. 31.
[206] *Elec. Rec.*, June, 1921, p. 377.

Cleaning.—The reflector cleans itself[207] every time the light is switched on or off in a unit which has two wiping blades, one moving over the inner surface of the reflector, the other over the lamp bulb.

Switches.—An improvement in attachments for pendant switches[208] consists of an arm-like case which extends from the canopy along the ceiling to the point where the switch cord is attached. The case is made of zinc-plated steel and has a rust-proof finish. It is expected to make possible a saving in wiring for wall switches. A pull-cord switch has been designed[209] similar to the ordinary type in appearance and to one described in last year's Report, which turns on the light immediately, but when it is extinguished, interposes a brief interval after the cord is pulled before the light disappears. The result is obtained by the use of a thermostatic device and enables one to see to leave the room, for instance, after the switch has been operated. The use of radium compounds to make pendant and wall switches visible in the dark, is increasing.[210]

PHOTOMETRY

Instruments.—A photometer, apparently of the portable type, has been brought out in Germany.[211] The lamp to be measured is placed in the back part of a light-tight cylindrical casing which is closed in front by a diffusing glass plate. In a central aperture of this plate is arranged a small light-tight hood which projects into the casing and contains the comparison or standard lamp. Attached to this hood is a cylindrical glass body arranged so that light from the comparison lamp reaches the opposite end, covered with a milk-glass plate, directly and by multiple internal reflections. This surface is viewed against the other surface as a background and the adjustment for brightness made in any one of a number of usual methods. Various modifications of the instrument have been suggested.

Most photometers in practical use to-day have a white diffusing screen which receives light from the two sources to be

[207] *Elec. Wld.*, Aug. 28, 1921, p. 456.
[208] *Elec. Rev.*, (U. S.), Nov. 13, 1921, p. 781.
[209] *Elec. Rec.*, July, 1921, p. 22.
[210] *Elec. Rec.*, May, 1921, p. 309.
[211] *Gas Jour.*, May 18, 1921, p. 383.

measured. When working with very low intensities or with a number of different sources between which discrimination is desirable, this method is not wholly satisfactory. It is rather remarkable that two instruments exactly the same in principle and differing only in detail have been described which avoid these objections by allowing the light from the source to be tested to impinge on a lens, after which it passes through a photometer cube to the eye. The other part of the cube receives light in a similar manner from a small comparison source. In one instrument[212] the balance is made by interposing a graduated absorbing wedge in the path of this light. The displacement of the wedge is observed by a telescope. In the other[213] a polarizing device is employed. It is claimed that illuminations of the order of 4×10^{-8} lux can be measured and among the uses for this type of photometer may be mentioned the measurement of the absorption of light by the atmosphere, observation of stars, brightness of faintly luminous phosphorescent substances, et cetera. It might be noted that the fundamental principle of these instruments is not new.

Considerable work was done during the war on the measurement and development of small incandescent lamps for signal work, in order to produce one that would operate as rapidly as possible. A new photometer was shown[214] at the last exhibition of physical apparatus of the London Physical Society, which was designed to measure the luminous intensity of a signal lamp at any interval of time after the current is turned on or off. It is thus able to measure the rate of incandescence and nigrescence. A cylindrical box painted white on its interior holds the lamp to be tested in its upper half, and the comparison lamp which is of the same type and which has been calibrated at various temperatures with an ordinary photometer, in its lower half. Each lamp illuminates a vertical slit covered with ground glass. An optical system presents to the eye of the observer two fields, one above the other, illuminated by the respective ground glasses. A revolving shutter provided with two slits rotates in front of the slits previously mentioned, and the mechanism which

[212] *Jour. d. Phys. et l. Radium*, Jan.-July, 1920, p. 25.
[213] *Phys. Zeit.*, Feb. 1, 1921, p. 71.
[214] *Engineering*, Jan. 28, 1921, p. 1104.

rotates the shutter carries contacts which provide current for the test lamp so that it can be lighted or switched off at any desired interval before the shutters open.

England has been the experimental centre of most of the work on the whitened cube as a substitute for the Ulbricht sphere in the measurement of mean spherical candlepower. Recently additional study and experiment have resulted[215] in the establishment of a set of ratios, covering a number of typical spherical light distributions. These ratios, when applied to the candlepower readings obtained with the cube correct them to true mean spherical values. In the Progress Report for 1914 reference was made to a new form of instrument called a glarimeter, which measured the gloss or degree of finish of a sheet of paper by means of its polarizing action on obliquely reflected light. At that time it was not put into general use because of some inherent defects and the difficulty of obtaining the optical parts. Improvements have now been made[216] and the defects remedied by replacing the optical system of the polarimetric part by a modified form of that used in the Pickering polarimeter.

Reference should be made to the report on Photo-Electricity which has been carefully compiled for the National Research Council and published in April, 1921, as No. 10, part 2 of volume II of the Bulletin.

Accuracy.—The subject of the precision obtainable with different types of photometers has been a matter of argument ever since accurate work has been possible. In connection with a study of heterochromatic photometry carried out several years ago, a very large number of observations were made with different observers and two different types of instruments which enable a comparison and analysis of the precision obtained.[217] It was found that with homochromatic light, experienced observers attained a precision of approximately 0.3 per cent with the Lummer and Brodhun contrast photometer, but that for heterochromatic work the precision decreased rapidly and except for certain observers of long practice, such measurements were not reproducible. For the flicker photometer the figure was

[215] *Elec.*, Feb. 11, 1921, p. 200.
[216] *Jour. of Op. Soc. of Amer.*, May, 1921, p. 213.
[217] *Jour. of Op. Soc. of Amer.*, Sept., 1920, p. 371.

approximately 0.75 per cent and was apparently not dependent on the color difference used. The ratio of the precision of the flicker to the Lummer and Brodhun photometer, expressed in terms of deviation of a single observer was approximately, for a color match 0.5; for the carbon-tungsten color difference, 1.0; and for the carbon-(gas-filled) tungsten color difference, 1.5.

Some short cuts and practical methods have been worked[218] out for the pre-determination of indirect or semi-indirect illumination, as well as some simplifications in the calculations for direct lighting.

PHYSICS

Reference was made in the Progress Report for 1919 to a hypothesis, according to which all chemical reactions are regarded as essentially photo-chemical reactions in which the energy of radiant heat or light is transformed into chemical energy, or vice versa. In a recent contribution[219] to this subject it has been pointed out that there are two consequences of this radiation hypothesis which should serve as a test of its validity. In the first place it is necessary that the reacting substance shall absorb radiation of the frequency required to produce the activation; and there must therefore be an absorption band which includes this frequency. In the second place the total amount of radiant energy absorbed must be sufficient to activate the required number of molecules. Examination of certain available data and experiments indicated that neither of these requirements was met and thus gave evidence against the hypothesis.

Light Sources.—A method has been worked[220] out for obtaining radiation having a spectral distribution like that of an ideal radiator or black body at any temperature from 3000°K to 7,000°K. The Arons chromoscope may be used for the experimental realization of such energy distributions. Numerous efforts have been made to obtain light from gases by heating them. When spectra were formed in a carbon-tube furnace heated to a high temperature and containing gases, it was thought that these spectra might be caused by the heating of the gas. But evidence has been produced[221] showing the complete absence of

[218] *Elec. Wld.*, Oct. 9, 1920, p. 721.
[219] *Jour. of the Am. Chem. Soc.*, Nov., 1920, p. 2190.
[220] *Jour. Op. Soc. of Amer.*, Mar., 1921, p. 178.
[221] *Science*, Dec. 31, 1920, p. 637.

emission lines in mercury vapor, argon, nitrogen, and hydrogen when heated to 3,200° K by means of a tungsten filament. No traces of a mercury emission line was found in the photograph of the spectrum of a tungsten spiral at 3,200° K operating in mercury vapor at approximately atmospheric pressure in a quartz bulb.

A new discovery has revealed an excitation to fluorescence of many substances[222] at temperatures above those at which ordinary phosphorescence disappears and fluorescence excited by light reaches extinction. It is produced by contact with a hydrogen-flame, and this effect is different from photo-luminescence and is not of the nature of temperature radiation. It is observed when there is actual contact of certain zones of a hydrogen flame with the material excited. Rapid reduction and oxidation appear to be the essential features. Many of the most striking examples are in substances not capable of being excited by light, *e. g.*, CaO, MgO, ZnO, SiO_2, exceptionally pure zinc sulphide, calcium sulphide, et cetera. Many strongly photo-luminescent compounds like calcium tungstate and willemite are inactive under flame excitation, while in others like sidot blende flame excitation continues to temperatures far above those at which photo-luminescence ceases. The range of temperature through which the phenomenon occurs is perfectly definite for each substance. The spectra, like those of the phosphorescent sulphides are broad-banded and when subjected to spectrophoto-electric measurement, are found to consist of numerous equidistant, over-lapping components.

Properties.—At various times reports have been made on experiments showing the effect of temperature on the transmission of glasses used as absorbing screens. An extension of this work to the effect on radiation in the region out to 5μ has indicated[223] that to within $\pm$ 8 per cent the variation in temperature of the glass produces no change in the transmission of infra-red radiation through the colored glasses tested.

Another elaborate study has been made[224] of the diffusion of light by the molecules of a transparent gas. Experiments were made to prove the diffusion and the latter measured quantitatively

[222]*Phys. Rev.*, Apr., 1921, p. 453.
[223]*Phys. Rev.*, Sept., 1920, p. 173.
[224]*Annales d. Phys.*, Jan.-Feb., 1920, p. 5.

by the process of photographic photometry. It was shown that the luminous intensity diffused by a transparent gas is not exactly proportional to the square of the refraction and that it appears to depend, as does also the degree of polarization, on the symmetry of the molecules.

Color.—After researches carried on over a period of forty years, a foreign investigator believes[225] he has solved the problem of the nature of color upon which vision is chiefly dependent. According to his work the black pigment of the eye is the seat of the transformation of light into heat. The heat thus produced is perceived as brightness, and all color perceptions are brought about by the mental reaction to the absence of heat stimuli. Details of the researches are to be published by the Research for the Textile Industries in Vienna.

An investigation has been made[226] of one of the older color-notation systems using a series of cards of graded neutral tints and also various colors, and in which a color is defined in terms of hue, brightness and purity. It was found that for a series of sample cards comprising nine neutral grays and three each, of red, yellow, green, blue, and purple, the reflection values marked on the cards agreed very well with observed results. It was recognized that in future the reflections of cards should form a geometric series or natural scale, in which the reflection coefficient of each card bears a constant ratio to that of the preceding one. Each color should be specified physically by spectral reflection curves of the actual cards, by monochromatic analysis on the basis of an established standard white and by its constants under prescribed conditions on a chromoscope.

Photoelectricity.—In the Progress Report for 1919, reference was made to a study of the color sensibility of photo-electric cells. Additional information on this subject is contained in a report[227] of experiments on thirty cells, made up with all the alkali metals and hydrides of sodium, potassium, rhubidium, and caesium. The color curves were so accurately determined that the wave-lengths of maximum sensitiveness were located within

[225]*Farben-Zeit.*, 1920, p. 50.
Chem. Abs., July 10, 1920, p. 2002.
[226]*Tech. Paper, B. of Stds.*, No. 167, 1920.
[227]*Astrophys. Jour.*, Oct. 1920, p. 129.

0.001 μ. It was found that as the atomic weight of the alkali metal increases, the maximum sensitiveness decreases, and the wave-length of maximum sensitiveness shifts toward the red. Differences were encountered with glass cells using neon instead of argon gas, and with cells made of quartz. The effect of illuminating a potassium cell for 525 hours was to increase its sensitivity by about 70 per cent, whereas a potassium hydride cell remained constant for 1,000 hours.

The effect of electric and magnetic fields on photoelectric phenomena seems to have attracted considerable attention among physicists. Having shown that zinc blende, which in its ordinary condition is an insulator and possesses no metallic properties, will conduct electricity when light is allowed to fall on it in the presence of a strong electric field, and that it exhibits a very marked selectivity, cadmium sulphide and mercury sulphide have been studied[228] and also exhibit this property. The increase of conductivity in the long wave-length spectral region falls on or near the limits of the optical absorption bands. In some other experiments[229] diamond crystals exhibited a photoelectric effect in strong electric fields (16,000 volts/cm.) The result was also found to vary with the wave-length of the exciting light. In the case[230] of a photoelectric cell in which bismuth was the sensitive element, a surrounding magnetic field of 600 gauss produced a diminution of 15 per cent in the photoelectric current.

PHYSIOLOGY

Theory.—A theory of vision has been proposed[231] which ascribes visual stimuli to the activity of light quanta in liberating electrons from the visual purple. In this view, color is appreciated in terms of the energy of the stimuli; brightness in terms of the concentration or density of the stimulus. The theory does not involve views regarding the origin of the quantum. In connection with the photoelectric theory of vision experiments have led to the conclusion[232] that neither the black pigment nor the retina as a whole is photoelectric to visual light. It is still con-

[228] *Zeit. f. Phys.*, 1920, p. 361.
[229] *Phys. Zeit.*, Nov. 1, 1920, p. 628.
[230] *Phys. Zeit.*, Nov. 1, 1920, p. 568.
[231] *Phil. Mag.*, Feb., 1921, p. 289.
Nature, Feb. 24, 1921, p. 827.
[232] *Phil. Mag.*, Mar., 1921, p. 347.

ceivable that the rhodopsin in the eye is actually photoelectric, but so immersed in inactive material that the electrons cannot escape.

A new equation for the visibility curve of the eye has been worked[233] out in a form similar to that of the Wien radiation law:

$$A = 1.132 \times 10^{25} \lambda^{-182} \epsilon^{\frac{-72.6}{\lambda}}$$

in which A is the value of the ordinate corresponding to any value λ plotted as abscissae, ϵ being the logarithmic base. The equation was worked out on the basis of a visibility curve obtained in Germany. Luminosity curves of twenty normal eyes, and for several color-blind persons, have been obtained[234] in Japan and suggest that the distribution of luminosity for American and Japanese eyes is the same. The maximum visibility was placed at 0.55 μ.

Under conditions of large contrasts in brightness only part of the difference is compensated by changes in the diameter of the eye pupil. Observations on vision of various degrees of fineness under conditions of temporary changes in illumination have indicated[235] that to avoid diminution of the accuracy of perception, the limit of contrast should be not more than 1 to 5 for fine work; 1 to 8 for mechanical work; 1 to 10 up to 1 to 15 for rough work.

Visual Acuity.—It has been estimated[236] that any thread which exists can be made ultra-microscopically visible, since a thread of diameter equal to one-millionth of the diameter of the hydrogen molecule would be just visible. It is concluded that with commercial microscope objectives, a serviceable image of a thread of 0.04 μ. in diameter may be obtained. Experiments to determine the difference, if any, between monocular and binocular sensibility as shown by the least perceptible brightness and the least perceptible difference in brightness indicated,[237] for a single observer, a greater sensibility for the binocular observations.

[233] *Zeit. f. Beleuch.*, Dec., 1920, p. 150.
[234] *Phys. Math. Soc.*, Japan, Sept., 1920, p. 177.
[235] *D. Opt. Worchenschr.*, No. 8, 1920, p. 129.
Phys. Ber., May 1, 1921, p. 538.
[236] *Proc. K. Akad. Amsterdam*, 1921, p. 705.
[237] *Psych. Bul., Feb.*, 1921, p. 74.

A study has been made[238] of visual acuity under very weak illuminations, such as those found at night and in twilight. The illumination at Groningen, The Netherlands, on a cloudless night in March or April, has been given as roughly 0.0003 m. c. With an illumination of this order of magnitude, the minimum vision as determined by the perception curves of Roelofs and Zeeman was $^1/_{40}$ to $^1/_{50}$ that obtained by clinically employed methods. Visual acuity appeared to depend on illumination, but large changes in illumination were accompanied by relatively small changes in visual acuity. Only a very small acuity is necessary to allow a free movement in twilight surroundings. Other experiments[239] to determine ability to see in twilight illumination indicated that visual acuity in daylight does not correlate significantly with light sensibility at any adaptation time, but does correlate moderately with visual acuity in a dim light.

An investigation of the effect of storms on visibility has led to the conclusions[240] that the obscuring power of a storm is directly proportional to the number of drops falling per second on a unit area and in no way depends on their size. It is also proportional to the coefficient of viscosity of the medium in which the drops fall and is inversely proportional to the acceleration due to gravity.

Experiments on retinal color vision by the fovea and peripheral regions of the eye indicate results[241] contrary to previously accepted views. It was found that "In the great majority of cases any color that can be seen at the fovea can be seen also at the periphery of the retina, although for a shorter time at the periphery. Some people, who appear to be hopelessly blind for certain colors at the fovea, can be made to see them in the same way that normal persons can be made to see chromas at the peripheral retina." Among the various factors[242] which appear to affect the chromatic response of the retina are the brightness of the pre-exposure and of the field surrounding the stimulus. The effect of these two factors has been studied using a rotary campimeter and standard color papers of the Hering series. The

[238] *Am. Jour. of Opthal.*, Oct., 1920, p. 770.
[239] *Br. Jour. of Psych.*, Apr., 1921, p. 289.
[240] *Nature*, Nov. 11, 1920, p. 343.
[241] *Am. Jour. of Phys. Optics*, July, 1921, p. 204.
[242] *Psych. Rev.*, Sept., 1920, p. 377.

widest angular limits of the color zones were obtained when the preexposure and surrounding field were of the same brightness as the color. It was decided that reproducible results cannot be hoped for in perimetric or campimetric determinations of the sensitivity of the peripheral retina unless the effects of the above two factors are eliminated by making the brightness in each case the same as that of the color employed, and working under constant illumination.

As a result of experiments in connection with observations on stars it has been concluded[243] that "The outer is more sensitive than the inner side of the retina for red or green light. This also holds for the average star. With green light the lower part is more sensitive than the upper: with red light and with the average star the reverse holds. With red light direct vision is more sensitive than averted, though with white stars, averted vision gives more sensitiveness. The advantage disappears as the star becomes red. With red light, the greatest sensitiveness is found in the upper and outer quadrants of the retina between 1° and 3° from the centre."

Color.—A statistical survey of the color vision of 1,000 students comprising 835 men and 165 women was made in England.[244] The test object was a piece of card board measuring 1.5 × 0.5 in. (42 × 15 mm.) which had on it a series of pairs of circular spots 1 mm. in diameter and colored with black, red, green and blue inks. It was placed under a microscope with a magnifying power of about 25 and the observers' color vision was measured by the distance out of focus at which he could just distinguish the different colors. The results were plotted in the form of frequency curves, such as those used by statisticians. Rejecting the observations of 14 red-green color-blind men, all the distributions were found to be "homogeneous. as variations about a mean; all the blue-green color-blindness and a part of the red-green color-blindness was thus an outlying part of a homogenous distribution."

The question has often been raised whether different colors and intensities of illumination (aside from the obvious importance of these factors in conditioning the effective functioning of the

[243] *Proc. Roy. Astron. Soc. of Canada*, Feb., 1921, p. 84.
[244] *Phil. Mag.*, Feb. 1921, p. 186.

visual apparatus) have any specific influence upon mental or motor efficiency. An investigation[245] on this subject led to the conclusion that it is not suitable for laboratory experimentation, but should be handled by a "group test." The work done indicated no difference in the hues in their effect on mental and physical activity. Certain results suggested a slowing of mental work under dim light and a stimulation under bright light. A spectrometer has been devised[246] for testing color blindness, which enables the exact size of the portions of the spectrum that appear monochromatic to be determined, and also the limits of vision at each end of the spectrum.

Eye Strain.—A committee composed of representatives of the Council of British Ophthalmologists, the Cinema Industry, the British I. E. S., the London County Committee, and the Physiological Society have studied[247] the subject of the cause of eye-strain at moving-picture shows, and the means of preventing it. As a result of a year's work they have made the following recommendations:

(1) That the angle of elevation subtended, at the eye of any person seated in the front row, by the length of the vertical line dropped from the center of the top edge of the picture to the horizontal plane passing through the observer's eye shall not exceed 35°, the height of the eye above the floor-level being assumed to be 3 ft. 6 in. (1.1 m.)

(2) That provided Recommendation (1) is complied with, the angle between the vertical plane containing the upper edge of the picture, and the vertical plane containing the observer's eye and the remote end of the upper edge of the picture should not be less than 25°.

While the subjects of flicker, film and mechanical defects, and brightness of screen, as well as conditions of artificial illumination in theatres, were investigated no recommendations were made.

Bibliography.—Attention should be called to a review[248] and summary of progress in visual science in 1919, which has a valuable bibliography in this field of work.

ILLUMINATION ENGINEERING

Daylight Saving.—In St. Louis and suburbs[249] daylight saving was defeated for 1921. In the Dominion House of Com-

[245]*Amer. Jour. of Psych.*, July, 1921, p. 326.
[246]*Soc. Arts Jour.*, Dec. 10, 1920, p. 40.
[247]*Ill. Eng.* (Lond.), June, 1920, p. 189.
[248]*Am. Jour. of Phys. Optics*, July, 1921, p. 232.
[249]*Mov. Pic. Wld.*, May 7, 1921, p. 48.
Elec. Wld., Dec. 11, p. 1181.

mons[250] (Canada) on April 11 it was stated that the Government would not introduce legislation to establish "daylight-saving" time. The committee in Congress[251] having jurisdiction over daylight saving bills decided the subject was not to be brought up for consideration, although three bills had been introduced, thus ending any possibility of making it national this year. In spite of the above evidence of objection to daylight saving, New York City has again adopted[252] it as the result of local option contained in a State Law, repealing state-wide action. Pennsylvania will not have the clocks turned back. New Hampshire, Connecticut, Massachusetts, and Rhode Island have all adopted the daylight saving schedule.

Skylight.—By combining with the Angström pyranometer[253] a recording device consisting of a lamp, galvanometer and a rotating photographic film, upon which the deflections are traced, continuous records have been obtained of sky brightness. For more than ten years such measurements have been made at Washington with the pyrheliometer. The above instrument checks very well with results obtained by the latter. The relative intensity throughout the visible spectrum of light from the zenith and various parts of the sky at different times of day from dawn onwards and under various atmospheric conditions, cloudy, misty and dull has been measured[254] at Sestola, 1,090 m. (0.63 mi.) above sea level, by a spectrophotometer, using an acetylene flame as a standard. The light was found to be selective having a decided preponderance of blue. It appeared that a pronounced reduction in the extreme violet was associated with the condensation of aqueous vapor. By making photographic exposures under colored filters selected to isolate various parts of the spectrum information[255] has been obtained as to the chromatic character of the light from the night sky. It was concluded that the night sky was much yellower or less blue than the (clear) day sky. Comparison with direct sunlight or moonlight showed that the night

[250]*Elec. Rev.*, (U. S.), Apr. 15, 1921, p. 487.
[251]*Elec. Wld.*, May 28, 1921, p. 1263.
[252]*Elec. Wld.*, Mar. 19, 1921, p. 667.
[253]*Mo. Weather Rev.*, Mar., 1921, p. 135.
[254]*Mo. Weather Rev.*, Jan., 1921, p. 26;
Soc. Spettros. Ital., July-Aug., 1920, p. 62.
[255]*Proc. Roy. Soc.*, *"A,"* Apr. 6, 1921, p. 10.

sky was of the same color quality as these. The conclusions favor that theory which regards the general light of the sky as an extention of the zodiacal light and not due to the scattering of sunlight by rarefied gas situated beyond the earth's shadow.

Data have been obtained[256] on the spectral transmission of the atmosphere for three types of weather conditions—(1) clear and cold, (2) over cast with high humidity, (3) rainy. Light from an incandecent lamp was reflected by a mirror 600 m. (0.4 mi.) distant and the intensity of this reflected light was compared by means of a spectrophotometer which the intensity of a beam directly from the lamp. The "clear and cold" condition gave slight evidence of selective absorption in the visible spectrum. The other two conditions gave a decrease in transmission for wave-lengths less than 0.54 μ. In the rest of the visible spectrum, the overcast and high humidity atmosphere gave curves having two maxima and a minimum, which are entirely lacking in curves for rainy weather. In all cases there appeared to be a reduction in transmission as wave-lengths increase above or decrease below certain values, the maximum of relative transmission falling within the range of vision.

Having found that within the errors of measurement the energy distribution in the spectrum of fixed stars agrees with that of a black body, a foreign experimenter has worked[257] out a method of determining the color, brightness and diameter of these stars. Since it was not possible to bring an experimental black body to the temperature necessary, recourse was had to a wedge-shaped red-glass filter. The comparison lamp was an incandescent lamp, the light from which could be varied by the use of crossed nicols. Calculation gave the temperature and the brightness and from these and the parallax, the star diameter.

Artificial Daylight.—The artificial daylight unit brought out in England a year ago has been further improved.[258] The difficulty of obtaining a medium with which to mix the pigments employed is said to have been met by a dye chemist. As a result of his discovery the pigments dried with a matt surface, the color being nearer the hue of the virgin powder than had been obtained by

[256] *Sci. Paper,* No. 389, B. of Stds., July 21, 1920.
[257] *Phys. Ber.,* Feb. 1, 1921, p. 161.
Publ. Astrophys. Obs., Potsdam, No. 76, 1920.
[258] *Ill. Eng.* (Lond.), Jan., 1921, p. 12.

any previously used mixture, and the medium having dried was uneffected by heat, not subject to change by oxidation and could be cleaned by light sponging.

Additional experiments[259] on a Japanese firefly have led to the conclusion that as in other cases the production of light is the result of oxidation. Two marine fishes[260] found in the Banda Islands of the Dutch East Indian Archipelago, and which for some years have been known to be luminous, have been studied and their light found to be that characteristic of luminous bacteria. It continues night and day without ceasing and quite independently of stimulation. The light is extinguished without a preliminary flash by fresh water and other bacteriolytic agents. The light ceases very quickly in the absence of oxygen but luciferin and luciferase cannot be demonstrated.

A German chemist has devised[261] a mathematical method of defining dye tints. It employs three figures, one representing the nearest color in an arbitrary color-circle divided into 100 tones, and containing the "pure color tones and also the purple color tones," the second giving the content of white and the third the per cent of black. It is claimed that every imaginable mixture of black and white with the pure color tone from the clearest purple to the dirtiest brown can be represented by this three-number designation. A colorimeter has been worked[262] out to study white pigments. It consists of a circular disk whose surface is covered with the material under observation and above which is another disk whose lower surface is covered with the same material. A non-selective mirror and a photometer cube bring both the incident light and the multiple reflected light from the two disks together in the field of the eye-piece. By successively placing in the eye-piece, color screens of wave-length 0.46 μ, 0.55 μ and 0.62 μ, and varying the intensity of incident light until photometric balances are established numerical values of the brightness of the above colors are obtained and are given as the color characteristics. Experiments with the instrument showed that the addition of a trace of lamp black, while reducing

[259] *Am. Jour. of Phys.*, Aug. 1, 1920, p. 137.
[260] *Science*, Apr. 1, 1921, p. 315.
[261] *Sci. Am. Mo.*, Mar., 1921, p. 231.
[262] *Proc. Am. Soc. Testing Materials*, 1920, p. 440.
Chem. Abs., May 10, 1921, p. 1408.

the brightness of all colors affects the red and green more than the blue, and the paint appears less yellowish and may be made almost non-selective. Measurements on a zinc oxide paint after the addition of lamp black showed a decrease in brightness of 3.5 per cent and an increase in hiding power of 17.5 per cent. These data should be of value in the preparation of white paints for Ulbricht spheres used in photometry.

An investigation[263] with observations covering a period of nine months has been made of the falling-off in brightness of a number of luminescent paints of the type used for illuminated watch dials, compasses, switch pendants, et cetera. The results showed that the intensity variation obeyed Rutherford's law very well, and the falling-off in brightness of such paints with different radium or radium-thorium content was calculated for a period of five years.

Measurements have been made[264] of the reflecting and diffusing power of a number of materials used to coat the projection screens of moving pictures theatres. The data have been presented in tables so that it is possible to find for a particular case the ratio of the brightness of the screen as observed by a person in the centre of the auditorium, to that of the brightness as observed by a person occupying a seat at the side and near the front, and also what screen surface will give the highest average reflecting power within a required angle.

In connection with the study of optical glass[265] the Bureau of Standards has investigated the dimensional changes of thirty-two different kinds of glass in the temperature regions between 20° C. and 650° C. The results show that glass passes through a critical expansion region in which the expansion rate increases by two to seven times. This critical region which for any one glass does not exceed 40° C. was found as low as 400° C. with some samples and as high as 575° C. with others. About 75° C. above the critical region the glass softens and contracts. The heat absorption observed by other experimenters occurs in the same temperature region as the critical change in the expansion.

[263] *Zeit. f. tech. Physik*, No. 5, 1920.
Tech. Rev., July 20, 1920.
[264] *Trans. of Soc. of Mot. Pic. Engs.*, Oct., 1920, p. 59.
[265] *Sci. Paper*, No. 393, B. of Stds., 1920.

The investigation has furnished the following information: the thermal expansion above and below the critical temperature; the temperature for most careful and thorough annealing; the upper limit for rapid annealing and the region where careful cooling is essential. A new glass has been developed[266] especially to provide greater diffusing power when used in the side walls and roofs of factory buildings, and thus help to conserve daylight. It is a wire-glass, every square inch of which has 900 prisms that appear like corrugations and have been scientifically designed in shape and size to give high diffusion.

Some years ago the discoloration of glass globes used for street lighting was shown to be due to ultra-violet radiation. A glass has been developed that[267] is said to be immune and spectrophotometric tests made after four hundred hours exposure showed no trace of discoloration. An old globe was cut in two, and one-half joined with a half made from the new glass. An 87-watt quartz mercury arc was so placed inside this composite globe that the two halves received equal exposure. A small piece of tin foil was put on the inside of each half to give protected spots to be used for comparison purposes. The absorption was found to be relatively greater for the region of 0.51 μ to 0.57 μ than for any other part of the spectrum. After four hundred hours the transmission at 0.53μ was 82.7 per cent of that of the unexposed part, having dropped from 89 per cent. Calculation showed that the discoloration of the old globe after four hundred hours was produced by approximately 4.5 joules of ultra-violet energy per square centimeter of glass surface. Another comparison has been made[268] of the relative value of sunlight and the mercury arc in testing the resistance of fabrics to deterioration by ultra-violet light. The results on some samples of Japanese silk showed that two hours' exposure to the mercury lamp produced a greater effect than fifteen days' exposure to sunlight, or say fifty hours of continuous sunlight.

Photography.—A new method has been discovered[269] whereby it is possible to take photographs of "solids in space," *i. e.*,

[266] *Sci. Amer.*, Apr. 30, 1921, p. 352.
[267] *Phys. Rev.*, Mar., 1921, p. 408.
[268] *Bull. de la Soc. d'Encourage p. L'Indus. Nat.*, Mar.-Apr., 1920. *Tech. Rev.*, Oct. 19, 1921, p. 70.
[269] *Sci. Amer. Mo.*, Mar., 1921, p. 259.

photographs which indicate three dimensions instead of two, in the manner of a relief map or of an image in a stereoscope. Every year sees a report of an apparatus which will take more photographs per second than any instrument previously made. The latest[270] makes use of a revolving prism system ground out of a single ring or plate of glass, in place of the previous elaborate framing shutter and intermittent film-movement mechanism. It is claimed that over 200,000 photographs per minute can be taken by this new instrument.

Experiments have been made[271] to determine for monochromatic light the relation between the blackening of photographic plates, the luminous intensity and the time. Three emulsions, —a slow one (Seed 23), a rapid one (Seed 27 x) and a very rapid one, (Seed Graflex)—were coated on plate glass and illuminated for various lengths of time with various intensities of monochromatic light of wave-lengths, 0.45 μ 0.55 μ and 0.65 μ. The exponent "t_P" in the expression I t_P = constant for equal blackening was shown to vary from 0.7 to 1.95, according to the emulsion, wave-length and intensity. It has been discovered[272] that an ordinary plate can be made panchromatic by a bath in sodium bisulphite followed by a lengthy washing. The sensitiveness may be carried well into the infra-red. Further experimentation is being carried on.

Data have been obtained[273] from experiments which give information necessary to construct color filters for use in photography. The filters are of the ordinary type consisting of two glass plates flowed with a colored gelatin and when dry cemented together with balsam. Absorption spectra limits have been obtained for a number of such filters when the light source is a blue-bulb gas-filled tungsten lamp.

Legislation.—After meetings held in various parts of the state during the year, and from hearings and information contained in over 5,000 communications, the Industrial Board of the Department of Labor and Industry of Pennsylvania has drafted a code[274] of rules covering head and eye protection. In the case

[270] *Sci. Amer.*, Apr. 9, 1921, p. 288.
[271] *Phys. Rev.*, Feb., 1921, p. 135.
[272] *Phot. Jour.*, Dec., 1920, p. 460.
[273] *Phys. Rev.*, Feb., 1921, p. 246.
[274] Tentative Draft of Code presented Aug. 26, 1920.

of glasses to protect against harmful radiation, it is provided that "lenses on helmet windows shall transmit not more than 0.081 per cent of radiant energy of any wave-length less than 406 mm. and not more than 1 per cent of the total radiant energy from a 200-watt, 110-volt lamp, operating as commercially rated (approximately 0.88 watt per spherical candle.)"

A school lighting code based on that of the Illuminating Engineering Society has been drafted[275] by the Industrial Commission of Wisconsin. It is designed to be more definite than the Society code with respect to requirements for natural daylight illumination and with respect to the glare and distribution of artificial light. Minimum permissable illumination values specified range from 0.5 ft. c. for storage spaces, 1 ft. c. for stairways and corridors, 2.5 ft. c. for assembly rooms, to 5 for laboratories, class and study rooms and 8 for sewing, drawing and drafting rooms.

The new automobile headlight law passed[276] in Ohio and made effective Aug. 15, 1921, makes it illegal to use a head-lamp not equipped with a device to prevent glare. Such devices must be approved by the Highway Commissioner. On the same day the new Massachusetts rules went into effect.

Societies.—The International Commission on Illumination, which was founded in 1913 to continue and extend the work of the International Photometric Commission, met[277] this year in Paris in the early part of July. Representatives were present from the United States, Great Britain, France, Belgium, Spain, Italy, and Switzerland. Numerous reports were presented at the five technical sessions. Definitions of three quantities and their units were decided upon, namely, luminous flux, luminous intensity and illumination. To elaborate on these units and to study and present proposals for extending the list to cover the whole subject of photometric nomenclature and standards, an International Committee was appointed to make a report at the next meeting. Three other similar committees were formed to cover the subjects of illumination in factories and schools, heterochromatic photometry and automobile head-lamps. Full details will

[275] *Elec. Rev.*, Nov. 13, 1920, p. 752.
[276] *Cleveland Plain Dealer*, Aug. 10, 1921, p. 6.
[277] *Elec. W'ld.*, June 18, 1921, p. 1449.

be found in the report to be presented to this Society. The National Illumination Committee of Great Britain has been working during the past year on proposals which were presented[278] at the meeting of the International Commission in Paris. Arrangements have been made with the Gas Referees for the transfer to the National Physical Laboratory for safe keeping and ease of reference, of the specifications and drawings covering the construction and method of use of the standard Vernon Harcourt pentane lamp.

The British Departmental (Home Office) Commission on Lighting of Factories and Workshops, whose work was temporarily stopped during the war, has resumed its investigations.[279] At present inquiries will be restricted to determining: (1) The conditions necessary to secure suitable lighting in factories and workshops; (2) the effects of mixed natural and artificial lighting with special reference to the lighting of underground workrooms.

In order to teach the proper and most efficient use of illumination, the National Electric Light Association has instituted a lighting department[280] whose function shall be to promote the installation of lighting demonstrations for the purpose of educating the public, manufacturers, merchants, and all others interested in illumination.

A new German Illuminating Engineering Society, called the "Lichttechnische Gesellschaft" has been formed[281] at Karlsruhe where the Technical High School possesses an institute for technical illumination. It is said that it will be patterned after the United States and British societies and recruit its members from the ranks of gas, electrical and other engineers, architects, medical men, official departments, et cetera. In line with the presentation to the public of the principles and practice of Illuminating Engineering, through the Baltimore and Philadelphia lecture courses, the original German Illuminating Engineering

[278] *Gas Jour.*, May 25, 1921, p. 434.
[279] *Gas Jour.*, Mar. 9, 1921, p. 614.
[280] *Elec. Wld.*, Sept. 11, 1921, p. 543.
[281] *Gas Jour.*, May 18, 1921, p. 380.

Society arranged,[282]—as forecasted in last year's Report,—a similar series of lectures at the Technische Hoch-schule at Charlottenburg last September. Fifteen subjects were covered, including photometry, hygiene, various light sources, projection, and different kinds of lighting,—interior and exterior. The lectures were subsequently published in book form.

BOOKS.

"Das Kugelphotometer," (Ulbricht'sche Kugel), Dr. Richard Ulbrecht, (R. Oldenbourg), Munich and Berlin, 1920. 31 illustrations and 3 tables, 110 pp.

"The Nature of Animal Light," Dr. E. Newton Harvey, (J. B. Lippincott Co.) Philadelphia, 1920. pp. x + 182.

Scienza e Tecnica dell' Illuminazione: Fotometria., Guido Peri. (S Lattes & Company) Turin, 1920, pp. vii + 479.

"Elements of Illuminating Engineering," A. P. Trotter (Sir Isaac Pittman & Sons), London, 1921, 103 pp.

"Lichttechnik," Bertelsmann, Bloch, Gehlhoff, Korff, Petersen Lux, Meyer, Mylo, Wechmann, and Wedding, (R. Oldenbourg), Munich, 1921. 49 tables, 591 pp.

"L'Eclairage Electrique," L. Barbillion and P. Bergeon, (Albin Michel), Paris, 1921. 87 Figs. and 160 pp.

"The Electric Lamp Industry," G. A. Percival, (Sir Isaac Pitman & Sons), 1920. 112 pp.

"Himmelshelligkeit, Himmelspolarisation und Sonnenintensitat,"C. Dorno, (Behrend & Co.), Berlin, 1919. 290 pp., 26 plates and 68 tables.

"La Production du Gaz d'Eclairage," Jacques Bouvier, (Ch. Beranger), Paris, 652 pp. 401 figures and 12 plates.

[282] *E. T. Z.*, July 8, 1920, p. 533.

REPORT OF THE COMMITTEE ON NOMENCLATURE AND STANDARDS—1921*

The Committee wishes to record at the outset the loss which it has suffered through the death of Dr. E. B. Rosa. There have been few men who have done as much to clarify and consolidate the nomenclature appertaining to illumination as Dr. Rosa. His powerful and consistent support of the proposal to replace the more or less heterogeneous and unreliable standards of candle-power existing not only in this country but in Great Britain and France as well by one reliable and uniform standard, and to secure the use of a common unit, maintained at least provisionally by the use of incandescent lamps, was one of the most influential elements toward bringing about the general adoption of the International Candle. The introduction and general acceptance of this unit have solved for practical purposes the fundamental problem in illuminating engineering. His active participation in the work of this Committee over a long series of years has contributed in large measure to such success as the Committee has enjoyed. Apart from the universal regret at the passing of a great leader in physical science, the Committee feels that its own loss has been an especial and peculiar one.

In view of the fact that the International Commission on Illumination was to hold a meeting in Paris in July of this year at which the acts of this Committee were to be submitted by the U. S. National Committee of the International Commission on Illumination for such action as the International Commission might see fit to take thereon, the Committee felt that to undertake any considerable or extensive revision of its previous work would not be advisable until after such meeting had been held.

The minutes of the Paris meeting of the International Commission on Illumination have now come to hand and the following summary of the actions of the Commission will be of great interest to the members of the Illuminating Engineering Society:

The Commission appointed committees to study the following questions and to report at the next meeting of the Commission:

*A report read at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

Heterochromatic photometry
Photometric definitions and symbols
Lighting in factories and schools
Automobile headlighting

It will be noticed that one of these committees parallels exactly the Committee on Nomenclature and Standards. The other committees represent subjects which have been an object of study of committees of the Illuminating Engineering Society for a number of years and to which the Society should be able to contribute materially. Furthermore, the Commission adopted certain definitions of photometric quantities. The official text of these definitions, which is in French, is as follows:

"Definitions Photométriques.

FLUX LUMINEUX: C'est le débit d'énergie rayonnante évalué d'après la sensation lumineuse qu'il produit.

Quoique le flux lumineux doive être regardé strictement comme le débit de rayonnement tel qu'il vient d'être défini, il peut cependant être admis comme une entité pour les besoins de la photométrie pratique, étant donné que, dans ces conditions, le débit peut être considéré comme constant.

L'unité de flux lumineux est le LUMEN. Il est égal au flux émis dans l'angle solide unité par une source ponctuelle uniforme de une bougie internationale.

ECLAIREMENT: L'éclairement en un point d'une surface est la densité de flux lumineux en ce point. ou le quotient du flux par l'aire de la surface lorsqu'elle est uniformément éclairée.

L'Unité pratique d'éclairement est le Lux. C'est l'éclairement d'une surface de un mètre carré recevant un flux de un Lumen uniformément réparti, ou l'éclairement produit sur la surface d'une sphère de un mètre de rayon par une source ponctuelle uniforme de une bougie internationale placée à son centre.

Par suite de certains usages reconnus, on pent aussi exprimer l'éclairement au moyen des unités suivants:

Si l'on prend pour unité de longueur le centimètre l'unité d'éclairement est le lumen par centimètre carré appelé Phot. Si l'on prend pour unité de longueur le pied, l'unité d'éclairement est le lumen par pied carré, appelé "Foot-Candle."

1 "Foot-Candle" = 10,764 Lux = 1,0764 milli-phot.

INTENSITE LUMINEUSE

L'intensité lumíneuse d'une source ponctuelle dans une direction quelconque est le flux lumineux par unité d'angle solide émis par cette source dans cette direction. (Tout flux émanant d'une source de dimensions négligeables par rapport à la distance à laquelle on l'observe peut être considéré comme provenant d'un point.)

L'unité d'intensité lumineuse est la Bougie Internationale telle qu'elle résulte des accords intervenus entre les trois laboratoires nationaux d'étalonnage de France, de Grande-Bretagne et des Etats-Unis en 1909*. Cette unité a été conservée depuis lors au moyen de lampes à incandescence électriques, dans ces laboratoires qui restent chargés de sa conservation.

*Ces laboratoires sont: le Laboratoire Central d'Electricité, à Paris, le National Physical Laboratory, à Teddington, et le Bureau of Standards, à Washington."

It was decided that the English translation of these definitions should be agreed upon by the English and American delegates to the Commission. A provisional translation furnished by the courtesy of Dr. Hyde, the American delegate to the Commission, is as follows. It is to be noted that this translation is subject to alteration as a result of the negotiations with the British National Committee.

Luminous Flux is the rate of flow of radiant energy evaluated with reference to visual sensation. Although luminous flux must strictly be defined as above, it may be regarded for practical photometric purposes as an entity, since the rate of flow is for such purposes invariable.

The Unit of Luminous Flux is the Lumen. It is equal to the flux emitted in a unit solid angle, by a uniform point source of one international candle.

Illumination at any point of a surface is the luminous flux density at that point, or, when the illumination is uniform, the flux per unit of intercepting area.

The practical unit of illumination is the Lux. It is equal to one Lumen per square-meter, or it is the illumination at the surface of a sphere of one meter radius due to a uniform point source of one international candle placed at its center.

As a consequence of certain recognized usages, the illumination can also be expressed by means of the following units:

Using the centimeter as the unit of length the unit of illumination is one lumen per square centimetre, and is called the

Phot. Using the foot as the unit of length, the unit of illumination is one lumen per square foot, and is called the Foot-Candle.

The Luminous Intensity (Power) or Candle Power of a point source in any direction is the flux per unit solid angle emitted by the source in that direction. (The flux from any source of dimensions which are negligibly small by comparison with the distance at which it is observed, may be treated as if it were emitted from a point.)

The unit of Luminous Power (Intensity) is the International Candle, such as has resulted from international agreement between the three national standardizing laboratories* of France, Great Britain and the U. S. A. in 1909.

This unit has been conserved since then by means of incandescent electric lamps in the laboratories which continue (or remain) charged with its conservation,

*These laboratories are the Laboratorie Central d'Electricite, Paris, the National Physical Laboratory, Teddington, and the Bureau of Standards, Washington.

It is a matter of great gratification to this Committee that one of its members, Past President of the Illuminating Engineering Society, Dr. E. P. Hyde, has been accorded the great honor of election as President of the International Commission on Illumination to hold office until such time as the next plenary meeting of the Commission is held, which is scheduled provisionally to take place in this country three years hence.

The matter of a generic term for "lighting unit" was considered by the Committee. In part I of the TRANSACTIONS was inserted a request that proposals for such a name or term should be sent in to the Committee. A considerable number of such proposals were submitted, and after considering them, the suggested term "luminaire" was deemed to be the most acceptable. The Committee therefore recommended the use of this term and expressed its wish that it might receive criticisms and further suggestions. In view of the fact that such criticisms and further suggestions were not received, the recommendation of the Committee was submitted to the Council of the Illuminating Engineering Society for such action as the Council might see fit to take. The term "luminaire" possesses the advantage that it is not a coined word but is a term already in use in the French language in this connection. The Committee considered that it is equally appropriate and understandable in English. It is hoped that the membership of the Society will inaugurate the use

of this term in their regular illuminating engineering work, with the expectation that the influence of their example will bring its general adoption.

The following resolutions were passed by the Committee:

RESOLVED: That this Committee communicate to the Research Committee of the Illuminating Engineering Society its hope and desire that that Committee may be able to direct investigation toward determining color values in terms of black body color temperature and arrive at standards of integral color suitable for adoption by this Committee.

RESOLVED: That this Committee communicate to the Research Committee that in the absence of suitable data on which definitions of glare can be based, it is suggested that the attention of the Research Committee be directed toward this question.

RESOLVED: That the rules and specifications for automobile headlighting of the Committee on Motor Vehicle Lighting of the Illuminating Engineering Society as promulgated by that Committee be hereby approved by this Committee.

A. E. Kennelly, Chairman
Louis Bell
C. O. Bond**
E. C. Crittenden
W. A. Dorey
E. J. Edwards
E. P. Hyde
C. O. Mailloux
A. S. McAllister
W. E. Saunders*
C. P. Steinmetz
C. H. Sharp, Secretary.

DISCUSSION

E. L. ELLIOTT: It occurs to me that if the French word "luminaire" were translated into the English word "luminary," it would make a good term.

W. J. SERRILL: In reading the report, I am uncertain as to whether this word "luminaire" is intended for a lighting unit or for a fixture. They are not necessarily the same things. The

*Mr. Saunders has registered disapproval of the term "luminaire."
**Deceased.

reference in the TRANSACTIONS, mentioned in this report, states that for which the committee is seeking, is the name for a lighting fixture. Now a lighting unit it seems to me is a lamp, whether incandescent, arc, or gas. A lighting fixture, on the other hand, is seemingly, the metal frame to which the lamps are attached, and which is fastened to the wall or the ceiling.

In modern times, these things are frequently combined, the lamp and fixture being made up into one piece. I am uncertain as to exactly what this word "luminaire" is intended to represent, whether it is the fixture without the lamp, the fixture all equipped with lamps, or just the lamp.

F. C. CALDWELL: The great thing is to get some name for this object which hitherto has been called a fixture, but which is not a fixture. It is not very important what the name is if we can only agree to use it. Since the Committee has selected this word, the thing for us to do is to get behind it, and see if we can put it over.

C. H. SHARP: Mr. Elliott made the suggestion that we might translate "luminaire" into "luminary," and then we would have the same thing in English, and it would be the thing that is going to be used anyway, and we might as well start with it. The trouble is we have "luminary" already more or less preëmpted by Sol and Luna, and a few others of that character.

Mr. Serrill went on to illustrate in a very vivid manner the need for the name that we are talking about. We want a name for the thing which is sometimes a fixture and sometimes isn't, but which is always something arranged with some sort of a light source in it. We call it a lamp, lighting fixture or something else. Why not call it a luminaire, and then we won't have this ridiculous thing of a movable fixture.

I want to say there were a number of suggestions sent in and they were all carefully considered. Most of the words suggested were coined words. The word "luminaire" is not open to the objection of being a coined word. It is self-explanatory to a large extent.

Another thing, as Prof. Caldwell said, we need a word that we will all use and understand, and if we work together, perhaps

we can secure its adoption, and I think that will be a real service. At the same time, let it be understood if the somebody will propose a better term than luminaire, I think it will be very gladly accepted by the Committee.

LOUIS BELL: The word "luminaire" is a word that we understand to express the general idea of a thing which carries a source of light, and that is the great advantage in the use of this word "luminaire." I think the word ought to be adopted, as far as translating the word into English, as it stands. It is an inclusive term. It connotes a device for carrying light, and being absolutely general, can be used in the same way as it is in French, where it is a perfectly good and regular word. I think we ought to take it over, as we have other words from the French which have proved very convenient in generalizing an idea.

E. D. Tillson: I should imagine that if everybody did not immediately adopt this word to the exclusion of all the words we have been using, it would still be valuable as a synonym.

For my own part, I have become very tired of having to write a word like "unit" so many times in a single report. Perhaps we must repeat the term three or four times in a paragraph, or dozens of times in the course of a report, and the constant repetition wears on both the writer and the reader. We search our minds for some other word and often settle on a poor substitute, for example, "lighting fixture," when speaking of something that is not a fixture at all—still we use it.

To me "luminaire" sounds well, at any rate, and extends our professional vocabulary in an acceptable way.

The only unfitness I can see in this word being standardized and used universally is, for example, its application to the discussion of stock yard or gas house lighting, where the word "luminaire" might appear a trifle high sounding to the average American—somewhat of a parlor term, and therefore not entirely appropriate.

W. J. SERRILL: What would the lighting device in this room be called?

C. H. SHARP: A luminaire. (Laughter)

W. J. SERRILL: Would the man who would manufacture that metal part and sell it with no lighting units, or lamps, attached, be a manufacturer of a luminaire?

C. H. SHARP: It would be a luminaire.

G. H. STICKNEY: The term "fixture" is sometimes used to designate the fixture alone, sometimes to designate the fixture complete with lamps, and sometimes when it is not known whether or not lamps are included. A similar use of the term "luminaire" does not involve any new complication on that score. So far as I know, there have been no serious complications from this use of the word "fixture" and I would not anticipate any trouble with the new term.

"Luminaire" seems to meet the objection, that "fixture" conveys an undesirable suggestion. The real question is whether the term will take. Experience is probably the only means of judging. We are all inclined to hesitate over new terms, which often come naturally after we become used to them, as in the case of "garage."

It is quite conceivable that by the time of next year's convention, we will be saying "luminaire" easily, and that "fixture" will before long begin to sound queer and obsolete. Let us hope that "luminaire" will prove as acceptable as "garage."

F. LEE FARMER: I think the present difficulty is not among the technical men, but among the trade, the people that handle these fixtures. I think the general meaning of the term, "lighting unit," among these electrical dealers throughout the country is a one-light unit, a one-light fixture, if you please, and in speaking of lighting fixture, the term is something here that we are selling. It might be well to consider that one point before adopting that term, whether it would be advisable to have some term to mean a single or one light unit.

G. B. REGAR: I think that this might also be confusing, for the reason that you invariably hear the work "fixture" applied to what we know as a unit and by this I mean an individual lamp, usually in an enclosing globe.

NORMAN MACBETH: I believe that this discussion is a result of the publicity of the manufacturers of the plug wall and ceiling

outlet devices recently perfected. They have selected their own name, "Elexilier" which will obviate the previous apparent absurdity of a removable fixture.

In England where lighting fixtures attached to walls and ceilings are not generally landlord-owned, the term "lighting fittings" is used. In our business the word "fixture" has not been the occasion of as much confusion as some other words,—for example, "lamp." In the gas industry, lamp is the accessory necessarily accompanying the light radiator. In the electrical field we have hand lamps, portable lamps, counter lamps, etc., and in all instances the source of light, the tungsten filament glass bulb, is also known as a lamp. The pre-emption of the word "lamp" probably occurred in the bare lamp days when a bulb was actually a lamp. To-day it is the cause of a great deal of confusion.

MR. WARD HARRISON: I believe that advertisers have found in order to popularize a word, quickly, for instance a coined word, it is always desirable to get one whose pronunciation is unmistakable even to uneducated persons. There would be a tendency to confuse "luminary" and "luminaire," and perhaps some would stumble over "luminaire" and decide they did not like it and stick to lighting fixture. If, in bringing it into the English, the final "e" were omitted, would it not clear up this objection?

SKY BRIGHTNESS AND DAYLIGHT ILLUMINATION MEASUREMENTS*

REPORT OF THE COMMITTEE ON SKY BRIGHTNESS;
H. H. KIMBALL, CHAIRMAN.

SYNOPSIS

This report has to do principally with measurements made with a Sharp-Millar photometer in a suburb of Washington, D. C., practically free from city influences, between April 5 and July 14, inclusive, 1921. Since it is the intention to continue the present observational program to cover at least a full year, the results given must be accepted as preliminary and subject to slight correction.

The sky conditions have been classified as (1) clear, (2) covered with thin clouds or dense haze, (3) covered with dense clouds or fog, (4) covered with clouds from which rain was falling, or (5) partly covered with clouds. The sky brightness and daylight illumination measurements have been grouped according to the above classification, and also according to the solar altitude. The means of sky brightness measurements are shown graphically by lines of equal brightness on stereographic projections of the sky.

The brightest sky as a whole is one covered with thin clouds or dense haze, although detached dense clouds may be brighter than thin clouds. The brightness generally increases with solar altitude, especially near the zenith. With a clear sky or one covered with thin clouds, the brightest area is about the sun, and the darkest point nearly 90° from the sun in his vertical. With dense clouds covering the sky the brightest area is near the zenith, with a nearly uniform diminution in brightness in all directions toward the horizon. With rain falling the sky brightness averages about half that with dense clouds without rain.

Table I gives the means of illumination from direct sunlight on a horizontal surface, and on a surface normal to the solar rays, and also the means of illumination from skylight on a horizontal surface, and on vertical surfaces differently oriented.

*A Report presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26 to 29, 1921.

With increase in solar altitude the increase in illumination on a horizontal surface from direct sunlight and skylight is marked; upon vertical surfaces the increase in illumination from skylight is not so marked, but the difference in the illumination on vertical surfaces differently oriented decreases. With a clear sky the illumination from skylight on vertical surfaces averages a little more than half the illumination from the same source on a horizontal surface; with a cloudy sky it averages a little less than half.

It is shown that by means of a simple mathematical equation the illumination can be computed from the sky brightness, and that the agreement between computed and measured illumination is close. An equation is also given for computing the shading effect of buildings or other objects, but the consideration of the reflection of light from such objects, and from streets and various kinds of ground surfaces, is reserved for a later report.

PHOTOMETRIC UNITS.

In photometric measurements, as in all others, a unit of measure is required. In the United States the International candle, is the unit generally employed.

For the purposes of this paper three definitions become necessary, as follows:

(1) *Luminous flux*, = *F*. = radiant power evaluated according to visibility, that is, the capacity to produce the sensation of light. The flux emitted in a unit solid angle by a point source of one candle power = one lumen.

(2) *The illumination on a surface* = flux density on the surface, = F/S, where S is the area of the surface. Therefore, the illumination varies inversely as the square of the distance from the source. Thus, a flux of one lumen produces a surface density of a foot-candle at a distance of one foot, a meter-candle at a distance of one meter, and a phot at a distance of one centimeter. There are 30.48 centimeters in one foot, and one phot = 929. foot-candles, since $(30.48)^2 = 929$.

(3) *The brightness* of a perfectly diffusing surface radiating or reflecting one lumen per square centimeter is one lambert. It is equivalent to a perfectly diffusing surface with an illumination of one phot.

SKY BRIGHTNESS MEASUREMENTS.

Apparatus. Most of the sky brightness measurements here considered have been made at Washington, D. C., with a Sharp-Millar Photometer, the brightness of a given point in the sky being compared with the brightness of a translucent glass plate at a known distance from an electric lamp of known candle power. In order to produce a color match the light from the sky is made to pass through an amber-colored gelatine film. The color match is good for direct sunlight, but light from the clear sky is blue and from a cloudy sky white, when compared with the electric-lamp light. Plates of neutral glass the transmission coefficients of which are known are employed to reduce the flux of light from the sky, and thus extend the photometric scale. The maximum possible scale reading when using the densest neutral plate available is about 7.5 lamberts. With a clear sky there is a small area around the sun that exceeds this brightness. With thin white clouds or dense haze present this area may extend to forty or fifty degrees below and on each side of the sun, and to a somewhat less distance above it.

The comparison lamp and all screens employed have been standardized at the Bureau of Standards. Check readings have also frequently been made at the same place, to detect possible changes in the lamp or screens. One of the Weather Bureau observers usually makes a part of these readings, and it may be stated that Mr. I. F. Hand, who has made most of the measurements for the Weather Bureau, has very nearly a normal eye. His readings are also above the average for smoothness.

Installation. The photometer is mounted in a wooden shelter on the roof of the College of History, American University, D. C., in a suburb 5.5 miles northwest of the U. S. Capitol, and 1.5 miles northwest of the U. S. Naval Observatory. The country to the south and west is thinly settled, and much of it is covered with forest. There are no manufacturing establishments or railroads within a radius of about three miles.. The University is therefore practically free from city influences, except with easterly winds, which are rare, and which bring some smoke from the city. The latitude of the University is 38° 56′ N, the longitude 77° 05′ W., and the photometer is 450 feet, or 137 meters, above sea level.

Fig. I gives a view of the photometer and its shelter. The latter is painted white on the outside and flat black on the inside. The upper edge of the sides of the house are on a level with the center of the elbow tube when the latter is horizontal. The photometer rotates on its support, and the latter carries a horizontal circle for measuring azimuths. The photometer is provided with a rather crude vertical circle for reading the angular height in which the tube is pointing. Resting on the top of the photometer is a screen used to cut off the direct solar rays in some of the daylight illumination measurements, which will be discussed later.

Observational Program. The source of the brightness of the sky is threefold: (1) direct diffusion of sunlight by the gas molecules and dust and other particles in the atmosphere; (2) reflection of light from the surface of the ground and other objects; (3) secondary diffusion of light by the atmosphere. Since the diameters of gas molecules are small as compared with the wave length of light, gases cause a greater proportion of scattering at the blue end of the spectrum than at the red end, giving the sky its blue color. The diameter of the dust and other particles in the atmosphere is generally large as compared with the wave length of light. These particles therefore reflect the white light from the sun, and greatly dilute the blue color of the sky.

When detached clouds are present they reflect a variable percentage of light that they receive, depending upon both the angle of incidence and the angle of reflection of the light. If the cloud layer is continuous, and everywhere of equal thickness and density, it approaches a matt surface, and its underside should be everywhere of equal brightness.

From the laws of diffusion or scattering and of the reflection of light, it follows that the brightness of the sky should be symmetrical on the two sides of a vertical circle through the observer and the sun, unless the cloud or haze distribution is unsymmetrical, or the surface of the earth under the two sides differs materially, as for instance, land under one side and water under the other. In order to economize the time required for making the measurements, it is assumed that the sky brightness at Washington is symmetrical on the two sides of the sun's vertical. Measurements are therefore confined to one side, and

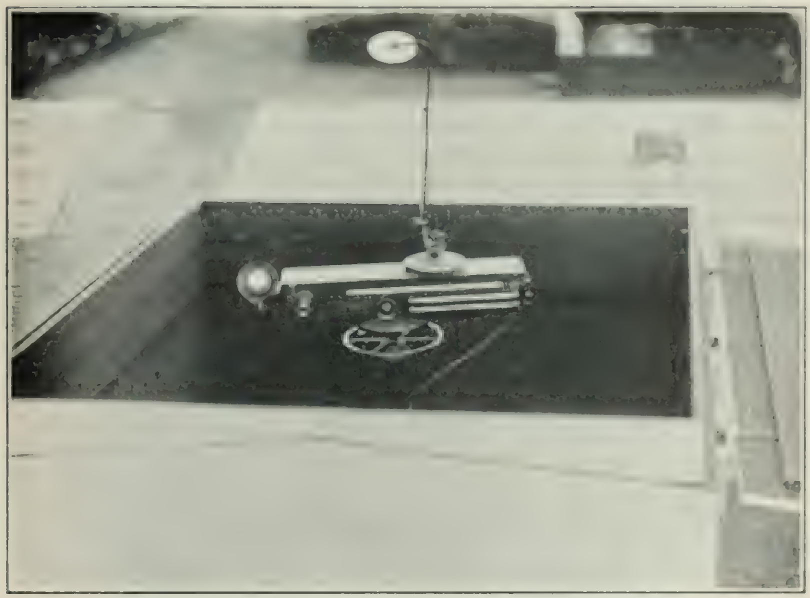


Fig. 1.—View of photometer and its shelter

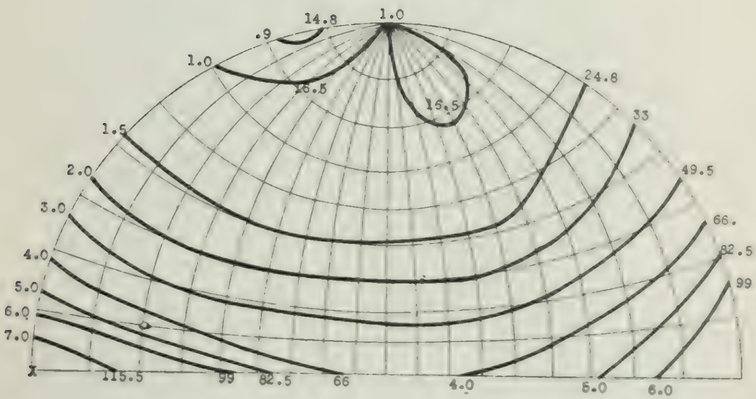
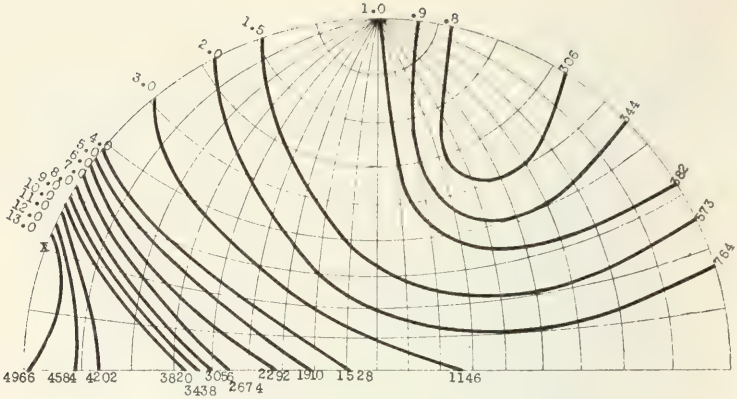
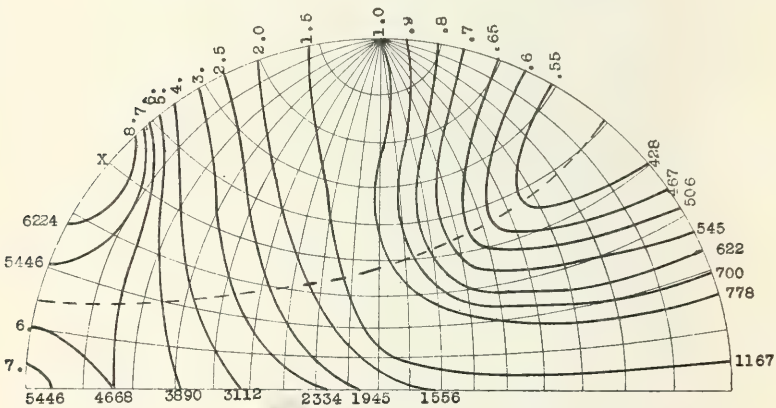
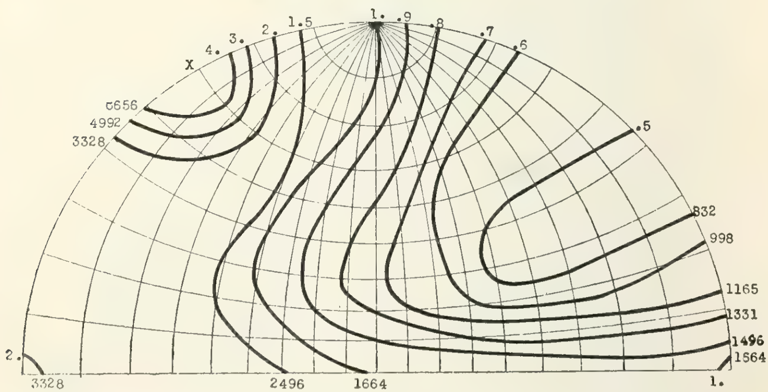


Fig. 2.—Average brightness of a clear sky in millilamberts. X = Sun's position.







Figs. 3, 4 and 5.—Average brightness of a clear sky in millilamberts.
X = Sun's position.

it is generally a matter of chance on which side they are made, except that if there appears to be smoke over the city the sky in that direction is avoided as far as possible.

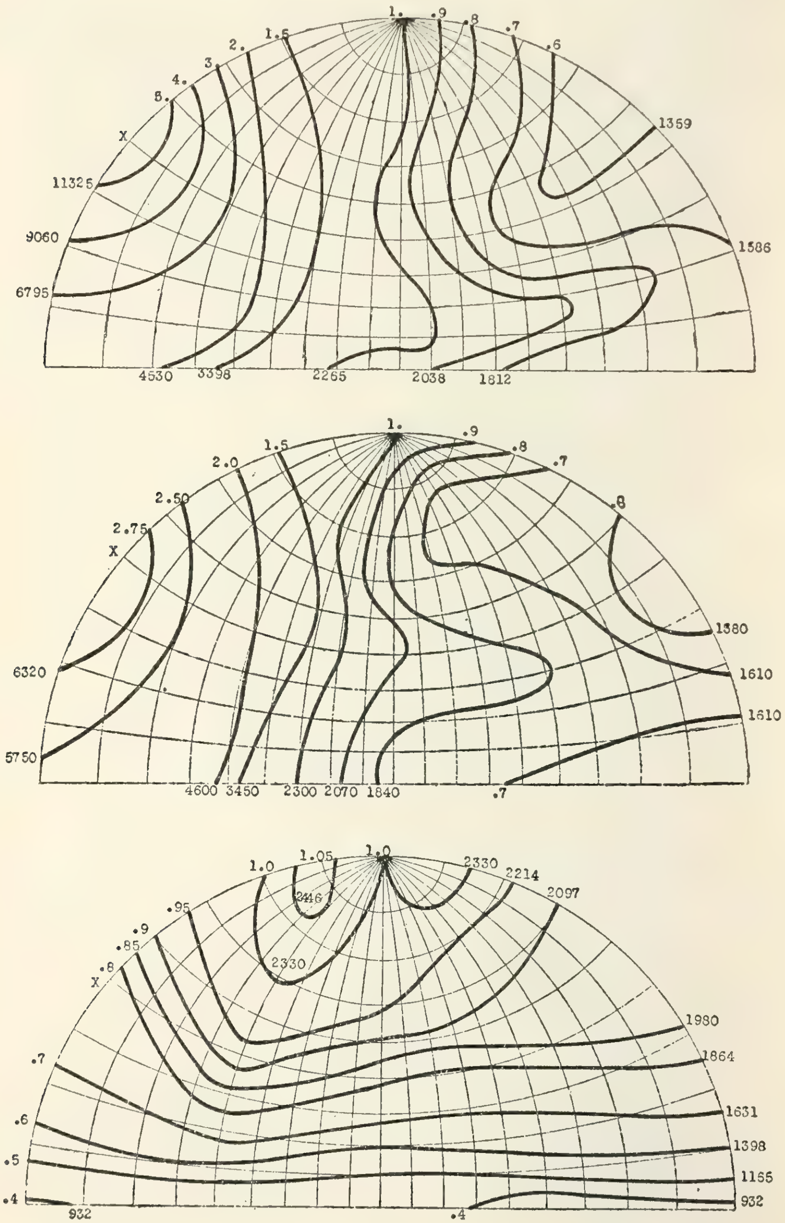
The observational program calls for a series of measurements as nearly as possible when the altitude of the sun above the horizon is 0°, 20°, 40°, 60°, and 70°, respectively. Not many observations are obtained in the summer with solar altitude 0° and 20°, and none can be obtained in winter with solar altitudes 60° and 70°. A complete series of readings includes measurements at 2°, 15°, 30°, 45°, 60°, 75°, and 90° above the horizon, on vertical quadrants of circles at azimuths 0°, 45°, 90°, 135° and 180° from the sun. Three photometric settings are made at each point, or 105 settings for each series, which latter requires from 10 to 12 minutes of time.

Classification of Observations. For the purpose of classifying the observations they have been grouped according to the solar altitude at the time of the measurement, and the state of the sky. Skies have been classified as follows: (1) clear when few or no clouds are present in the half of the sky measured; (2) overcast with thin clouds or dense haze; (3) completely covered with clouds or dense fog, so that neither the sun nor blue sky can be seen; (4) overcast with clouds from which rain or snow is falling; and (5) partly overcast with clouds. This latter includes all that cannot be included in the first four classifications.

Summary of Measurements. Figures 2 to 13, inclusive, are based upon the means of all the observations obtained at Washington, with the specified solar altitudes and sky conditions, between April 5 and July 14, inclusive, 1921. They represent about 25 clear, 25 cloudy, and 15 partly cloudy half days, 15 days with the sky covered with thin clouds or haze, and 10 half days with rain falling.

Half the sky only is shown, in stereographic projection, and the brightness is given in millilamberts. In Figs. 2 to 10, inclusive, and Fig. 12, the half of the sky to one side of the sun's vertical is shown; in Figs. 11 to 13, the half of the sky that is farthest from the sun.

In Figs. 2 to 9, inclusive, the sky is divided into zones 10° in width that are concentric about the zenith; in Figs. 10 and 12



Figs. 6, 7 and 8.—Average brightness in millilamberts of a sky covered with thin clouds, partly covered with clouds, and covered with dense clouds. X = Sun's position.

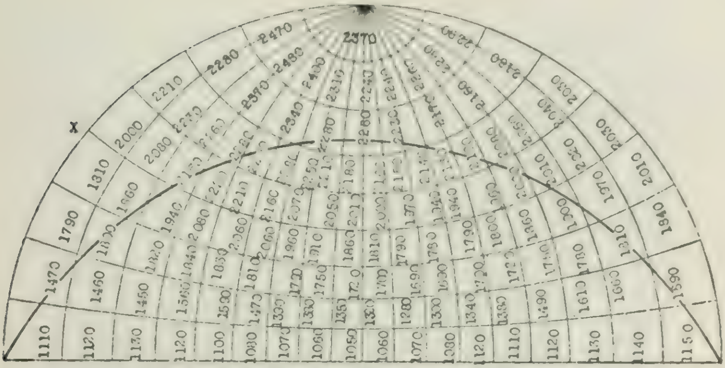


Fig. 9.—Average brightness in millilamberts of different parts of a cloudy sky. Y=Sun's position.

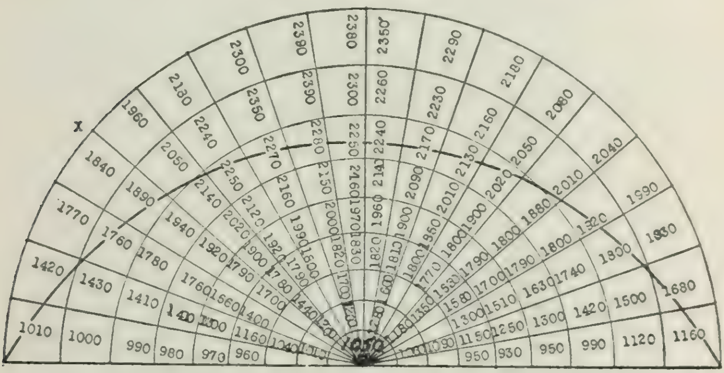


Fig. 10.—Average brightness in millilamberts of different parts of a cloudy sky. X = Sun's position. (10° zones concentric about a point 90° from the sun.

the zones are concentric about a point on the horizon 90° in azimuth from the sun; in Figs. 11 and 13, about a point on the horizon 180° in azimuth from the sun. The sky is divided into these three sets of zones for convenience in computing the illumination from skylight upon a horizontal surface, and upon vertical surfaces facing 90° and 180° in azimuth from the sun respectively.

Figures 2 to 5, inclusive, show by means of lines of equal brightness the mean brightness of a clear sky, not only in millilamberts, but also with reference to the zenith brightness, for solar altitudes 0°, 20°, 40°, and 60°, respectively. It will be

noticed that with the sun on the horizon and the sky clear, there is nearly a symmetrical distribution of brightness about the zenith, with a marked increase in sky brightness toward the horizon, and a slight increase in both directions from azimuth 90° from the sun. The brightest sky is in the immediate vicinity of the sun.

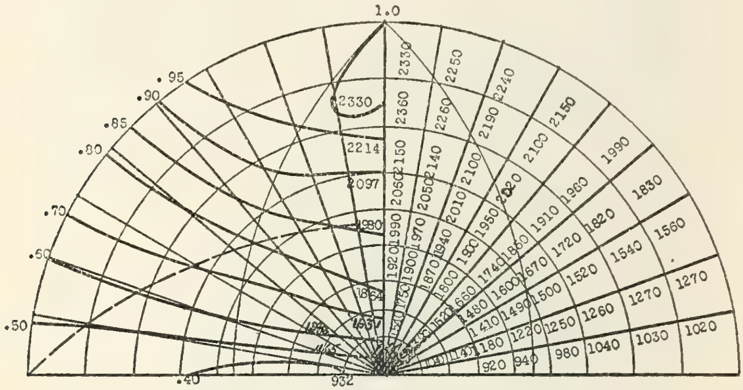


Fig. 11.—Average brightness in millilamberts of the half the sky opposite the sun when cloudy. Solar altitude = 40°.

With increased solar altitude the above brightness distribution is maintained. The darkest point in the sky is a little less than 90° from the sun, and the dark line or valley in the sky, starting at the darkest point, does not quite reach the horizon, but passed between the sun and the horizon. The brightness in the zenith, and, indeed, the general sky brightness, increases with the solar altitude, except on the horizon underneath the sun.

Dorno[1] found that with the sun 30° above the horizon its surface brightness is 1,000,000 times the brightness of the clear sky in the zenith.

It is also of interest to note that Dorno's measurements show a brighter horizon and a brighter sky opposite the sun than is indicated by the Washington measurements, probably on account of the amount of light reflected from the snow-covered Alps.

[1] Dorno, C. Himmelshelligkeit, Himmelspolarization und Sonnenintensitat in Davos 1911 bis 1918. · Voroffentlichungen der Prussischen Meteorologischen Instituts, No. 303, Abhndlungen Bd. VI.

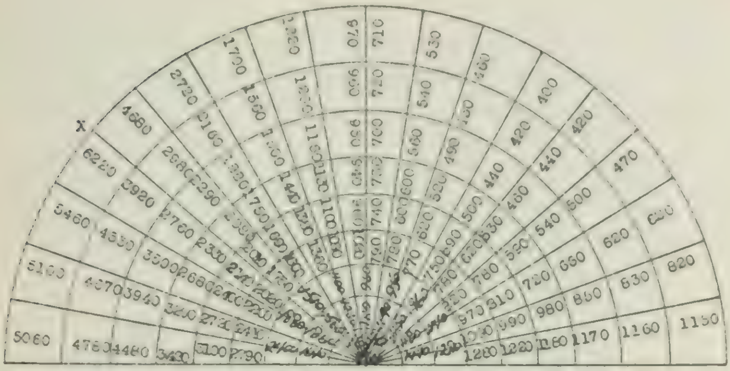


Fig. 12.—Average brightness in millilamberts of different parts of a clear sky. X = Sun's position. (10° zones concentric about a point 90° from sun.)

On the other hand, unpublished measurements made by F. W. Little at Key West and Sand Keys, Fla., and off Long Island, N. Y., give a darker horizon, and a darker sky opposite the sun

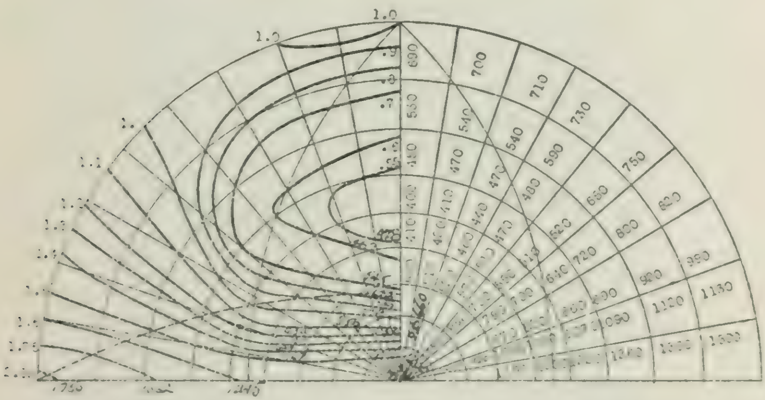


Fig. 13. = Average brightness in millilamberts of the half the sky opposite the sun when clear. Solar attitude = 40°.

than is shown by the Washington measurements, probably because Little's measurements were made principally over a water surface, which is a poor reflector of light. Dorno found the albido of a snow surface to be from 60 per cent to 74 per cent, the latter for freshly fallen snow, as compared with 6 to 7 per cent for grass covered ground, and 2 per cent for a water surface.

Figures 6, 7, and 8 also show by means of lines of equal brightness the brightness of the sun when covered with thin clouds or dense haze, partly covered with clouds of various types, and completely covered with dense clouds or fog, respectively, with the sun at altitude 40°.

It will be seen from Fig. 6 that a sky covered with thin clouds or dense haze is the type of sky that is brightest, especially in the vicinity of the sun. On the horizon the brightness does not greatly exceed that with a clear sky.

With the sky partly overcast with clouds the brightness varies from that of a clear sky to that with a sky covered with thin clouds or dense haze. Luckiesh[2] and Aldrich[3], working independently, have found that dense white clouds reflect about 78 per cent of the light that they receive, and that the cloud surfaces may be from five to ten times as bright as adjacent patches of blue sky.

With the sky covered with dense clouds or fog the sky shows an entirely different distribution from the types already considered. The brightest point is near the zenith, from which point there is a nearly uniform diminution in brightness in all directions to the horizon, except that there is a slight minimum of brightness in 90° azimuth from the sun.

With the rain falling the brightness distribution is much the same as with a cloud or fog-covered sky, but the absolute brightness averages only about one half as great.

It is to be noted that a cloud or fog-covered sky is not uniformly bright on its lower surface when viewed from a given point. It departs markedly from a perfectly diffuse reflecting or radiating surface. This is no doubt partly accounted for from the fact that neither the upper nor the lower surface of a cloud layer is smooth, but contains numerous humps and hollows. When viewed at a considerable angle from the normal the darker humps on the lower surface hide the brighter hollows or thin places in the clouds, to a considerable degree.

[2] M. Luckiesh. The Visablity of Air Planes. *Jour. Franklin Institute*, 1919, Vol. 187 p. 306.

[3] Aldrich, L. B. The Reflecting Power of Clouds. *Smith, Misc. Coll.*, Vol. 69, No. 10.

Figure 9 gives the average brightness of spherical polygons measuring 10° on a side, as determined from the lines of Fig. 8. This is a convenient method of representing sky brightness when computations of the illuminations on a horizontal surface are to be made.

Figure 10 shows the same sky brightness as in Figs. 8 and 9, but with the 10° polygons conveniently arranged for computing the illumination on a vertical surface facing 90° in azimuth from the sun.

In Fig. 11 the two quadrants of the sky shown are on opposite sides of the sun's vertical, and the brightness of each is that of the quadrant in Figs. 8 to 10, inclusive, that is farthest from the sun. The brightness of one quadrant is shown by means of lines of equal brightness, while on the other the brightness of the 10° polygons is given, conveniently arranged for computing the illumination on a vertical surface facing 180° in azimuth from the sun.

Figures 12 and 13 are similar to Figs. 10 and 11, respectively, except that they represent clear sky conditions with the sun 40° above the horizon, as in Fig. 4.

DAYLIGHT ILLUMINATION MEASUREMENTS.

A compensated test plate has been employed in measuring the intensity of daylight illumination. That is to say, the plate is so constructed that the light intensity from a given source varies closely with the cosine of the angle of incidence at which the light is received. After each series of sky brightness measurements the following illumination measurements are made:

(1) Total solar and sky illumination with test plate horizontal.

(2) Total solar and sky illumination with test plate normal to the sun.

(3) Sky illumination with test plate normal to the sun.

(4) Sky illumination with test plate horizontal.

(5) Sky illumination with test plate facing 90° from the sun in the sun's vertical.

(6) Sky illumination with test plate vertical, and facing in azimuth, 0°, 45°, 90°, 135°, and 180° from the sun, respectively.

When the sun is shining use is made of the shade in Fig. 1 to cut off direct solar radiation when desired.

TABLE 1. Daylight Illumination Measurements.

Mean solar altitude	Solar Illumination. Normal Incidence	Solar Illumination. On horizontal surface	Sky Illumination. On horizontal surface	Sky Illumination. On vertical surface. Azimuth from sun 0°	45°	90°	135°	180°
°	F. C.	F. C.	F. C.	F. C.	F. C.	F. C.	F. C.	F. C.
		Clear Sky						
23.9	4873	2023	996					
41.5	7922	5560	1343	1575	1325	849	575	534
60.2	8972	7648	1735	1445	1279	960	758	578
71.1	9714	9136	1600	1291	1074	947	824	699
		Partly Cloudy Sky						
40.0	4520	3146	3036	2799	2470	1561	1021	762
60.0	4551	3090	3977	2312	2057	1596	1777	1228
70.0	4281	3724	4360	2176	1922	1653	1537	1515
		Cloudy Sky						
40.0			1989	925	926	849	792	782
60.0			2146	881	941	977	932	929
70.0			3446	1294	1254	1210	1222	0931

Table 1 summarizes the illumination measurements, which cover only the period from May 7 to July 14, 1921. The increase in direct solar illumination with increase in solar altitude, especially on a horizontal surface, is clearly shown, and also the increase in sky illumination on a horizontal surface. The increase in the illumination on vertical surfaces is not so marked, but the difference between the illumination on surfaces facing 0° and 180°, respectively, in azimuth from the sun, grows less with increased solar altitude.

Direct solar illumination measurements show extreme departures from the mean value of about ± 30 per cent with solar altitude 40°, ± 20 per cent with solar altitude 60°, and ± 12 per cent with solar altitude 70°. Sky illumination on a horizontal surface with few or no clouds present, shows variations from the mean of about ± 40 per cent regardless of solar altitude. In the case of both solar and sky illumination, however, the extreme plus departures are greater than the extreme minus departures. The direct solar illumination measurements average higher than those obtained by me at Mount Weather, Va. in 1913 - 1914.[4]

[4]*Monthly Weather Review*, December, 1914, p. 652.

The illumination on vertical surfaces with the sky partly covered with clouds shows variations of about $\pm$ 60 per cent on each side of the mean. Or, roughly, the maximum sky illumination measured on a vertical surface has been about four times the minimum illumination measured on the same surface. Illumination from a cloudy sky shows about the same order of variation.

COMPUTATION OF DAYLIGHT ILLUMINATION FROM SKY BRIGHTNESS MEASUREMENTS.

The illumination on a horizontal surface may be computed from sky brightness measurements as follows:

Suppose the hemispherical sky surface, of radius r, to be divided into elementary horizontal zones, and let the angular altitude of these zones above the horizon $= \theta$. Then the radius of any zone $=$ r cos θ, and the circumference $= 2^{\pi}$r cos θ. Let the width of the zone $=$ r d θ, its area $= 2\pi\ r^2 \cos\theta\ d\ \theta$. Let the sky brightness everywhere $=$ one unit, and the horizontal light intensity due to the brightness of an elementary zone $=$ dI.

$$\text{Then } I = \int 2\pi\ r^2 \cos\theta \sin\theta\ d\ \theta$$
$$= \pi\ r^2 \sin^2\theta \qquad (1)$$

Taking zones 10° in width as in Figure 9, we obtain the following relative values of the vertical component of the illuminating power of each zone.

For $\theta^{10°}_{0°}$, $I_0^{\pi/18} = 0.030\ \pi r^2$; $I^{10°}_{0°} = 0.030$

For $\theta^{20°}_{0°}$, $I_0^{\pi/9} = 0.117\ \pi r^2$; $I^{20°}_{10°} = 0.087$

For $\theta^{30°}_{0°}$, $I_0^{\pi/6} = 0.250\ \pi r^9$; $I^{30°}_{20°} = 0.133$

For $\theta^{40°}_{0°}$, $I_0^{\pi/4.5} = 0.43\ \pi \mathrm{I} r^2$; $I^{40°}_{30°} = 0.163$

For $\theta^{50°}_{0°}$, $I_0^{5\pi/18} = 0.587\ \pi r^2$; $I^{50°}_{40°} = 0.174$

For $\theta^{60°}_{0°}$, $I_0^{\pi/3} = 0.750\ \pi r^2$; $I^{60°}_{50°} = 0.163$

$$\text{For } \theta_{0^\circ}^{70^\circ},\ I_0^{7\pi/18} = 0.883\ \pi r^2;\ I_{60^\circ}^{70^\circ} = 0.133$$

$$\text{For } \theta_{0^\circ}^{80^\circ},\ I_0^{4\pi/9} = 0.970\ \pi r^2;\ I_{70^\circ}^{80^\circ} = 0.087$$

$$\text{For } \theta_{0^\circ}^{90^\circ},\ I_0^{\pi/2} = 1.000\ \pi r^2;\ I_{80^\circ}^{90^\circ} = 0.030$$

The relative values given above are to be multiplied by the average measured brightness of each zone, as determined for example, from charts similar to those in Figs. 9 to 12, inclusive. The sum of the products multiplied by 0.929 gives the resulting illumination in foot-candles.

TABLE 2. Sky Brightness in Terms of Zenith Brightness. Overcast Sky. Mean of Measurements Made on May 25, 26 and 27, 1921.
Solar Altitude, 40°.

Azimuth from sun	Altitude of point observed							Zenith brightness ml.	Measured illumination. Vertical surface
°	2°	15°	30°	45°	60°	75°	90°		
0	0.476	0.715	1.069	1.174	1.166	1.173	1.00	2098	978
45	0.439	0.624	0.835	0.977	0.980	0.966	1.00	2290	1026
90	0.320	0.433	0.611	0.722	0.936	0.929	1.00	2564	799
135	0.342	0.477	0.663	0.708	0.941	1.102	1.00	2764	725
180	0.325	0.475	0.670	0.641	0.806	0.826	1.00	2932	693
Mean								2530	
Horizontal surface illumination									1718

The above method is appliable to the determination of the illumination upon vertical surfaces facing in any desired direction, provided the 10° zones are properly chosen, for instance, as in Figs. 10 to 13, inclusive, except that one half the sum of the products above named is to be multiplied by 0.929 to obtain the illumination in foot-candles.

Example. The data in Table 2 are the means of three series of readings obtained on May 25, 26, and 27th, 1921, with overcast sky conditions, and the sun 40° above the horizon. Table 3 illustrates the method of computing the illumination intensity on a horizontal surface, and on vertical surfaces facing 180° and 90° from the sun, respectively, from charts constructed from the data of Table 2.

It will also be noted that the measured illumination on vertical surfaces is a little greater than the computed, perhaps because

TABLE 3. Illumination Computed from Sky Brightness.

On Vertical Surface 180° from Sun.

(1)	(2) Computed from Eq. 1	(3) From chart	(4)=(2)×(3)	(5)=(4)×.929	(6) (From Fig. 11	(7)=(4)·(6)	(8)=(7)·.929
Sky zone Degrees from normal	Relative value	Average sky brightness	Hor. comp. of sky brightness	Illumination	Shading by buildings on opposite side street h = w		
°		ml.	ml.	F. C.	per cent.	ml.	F. C.
0-10	0.030	949	28.47		100.0	28.47	
10-20	0.087	1068	92.92		100.0	92.92	
20-30	0.133	1230	163.59		100.0	163.59	
30-40	0.163	1357	221.19		100.0	221.19	
40-50	0.174	1460	254.04		81.9	208.00	
50-60	0.163	1537	250.53		38.6	96.90	
60-70	0.133	1672	222.38		19.5	43.30	
70-80	0.087	1832	159.38		9.5	15.10	
80-90	0.030	1828	54.84		3.2	1.75	
		Total	1447.34		Total	871.22	
		½ Total	723.7	672	½ Total	435.61	405

On vertical surface 90° from sun.					On horizontal surface.		
					Sky brightness		F. C.
(1)	(2) Computed from Eq. 1.	(3) from chart	(4)=(2)×(3)	(5)=(4)×.929	(6) From chart	(7)=(2)·(6) Vertical component	(8)=(7)·.929 Illumination
					ml.	ml.	
0-10	0.030	980	29.40		1048	31.44	
10-20	0.087	1075	93.52		1352	117.62	
20-30	0.133	1232	163.86		1693	225.17	
30-40	0.163	1439	234.56		1957	318.99	
40-50	0.174	1581	275.09		2057	357.92	
50-60	0.163	1787	291.28		2269	369.85	
60-70	0.133	1908	253.76		2404	319.73	
70-80	0.087	2018	175.44		2498	217.48	
80-90	0.030	2091	62.73		2530	75.90	
		Total	1579.64			2034.10	1890
		½ Total	789.8	734			

the blackened walls of the photometric shelter, which extend up to the level of the center of the photometer test plate when the photometer tube is horizontal, reflect from 2 to 3 per cent of the light that falls upon them. On the other hand, the computed illumination on a horizontal surface is 10 per cent greater than the measured; but this discrepancy is not great when we consider the variations in sky brightness indicated by the zenith brightness measurements.

THE SHADING EFFECT OF HIGH BUILDINGS

In Table 3, in connection with the illumination on a vertical surface facing 180° from the sun, the amount of skylight excluded by buildings on the opposite side of the street is considered.

Let w = the width of the clear street space, h = the height to which opposite buildings extend above the center of a window that is under consideration, a = the angle between a line normal to the window surface and a horizontal line drawn to a point p on the row of buildings, and θ the angular height of the building above the point p, as seen from the center of the window. Then

$$\tan\theta = \frac{h/w}{\sqrt{1 + \tan^2 a}} \qquad (2)$$

Let h = 2w, w, and ½w, respectively, and let the row of buildings be of infinite length. We obtain the following relations between a and θ.

	a =	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
h/w = 2,	θ =	63°.4	63°.1	62°.0	60°.0	56°.9	52°.1	45°.0	34°.4	19°.1	0°
h/w = 1,	θ =	45°.0	44°.6	43°.3	40°.9	37°.5	32°.7	26°.6	18°.9	9°.8	0°
h/w = ½,	θ =	26°.6	26°.2	25°.2	23°.4	21°.0	17°.8	14°.0	9°.7	5°.0	0°

On Figs. 9 and 10 the area below the broken line represents the sky area cut off by a row of buildings where h = 2w, on Fig. 11 it represents the sky area cut off by buildings where h = w, and on Fig. 13 it represents the area cut off by buildings where h = ½w.

It is to be noted that any obstruction on the horizon cuts off the portion of the sky that is most efficient for lighting vertical surfaces, such as the side windows of buildings, and especially if the sky is clear.

It is possible to extend these computations so as to determine the illumination resulting from exposure to any known area of the sky, which would, of course, vary with the character of the sky and the time of day.

The reflection of light from ground surfaces, and from the walls of buildings and other objects, is an important subject that will receive future consideration.

SUMMARY.

From measurements of sky brightness now being made, charts are prepared showing the brightness of the sky under different conditions of cloudiness and with the sun at different altitudes.

On these charts the sky has been divided into ten-degree zones concentric about the zenith, or about selected points on the horizon, and the brightness of these zones determined for typical sky conditions.

It is shown that with these data it becomes possible to compute the illumination resulting from sky brightness on a horizontal surface and on vertical surfaces facing the selected points on the horizon.

A method is also shown for taking account of the shading effect of buildings and other objects. It therefore becomes possible to compute for average sky conditions of the various types the illumination that results from exposure to any given portion of the sky at any hour of the day or season of the year. The standard deviations and the extreme deviations from these mean values may also be given.

While each case becomes a separate and distinct problem, it is believed that for the more important industrial centers tables may be prepared covering a majority of cases that will arise, and perhaps differentiating between good and bad illumination.

ADDENDUM.

Between July 19 and August 13, inclusive, 1921, measurements of sky brightness and the intensity of daylight illumination were made by the Chairman in the city of Chicago. The observational program for sky brightness measurements was the same as that followed at Washington, but the illumination measurements were confined to the illumination from sunlight and skylight combined, and from skylight alone, on a horizontal surface, and also on a surface normal to the direct solar rays.

Between July 25 and August 6, inclusive, the measurements were made from the top of the dome of the Federal Building, about 300 ft. above the ground, in the heart of the Loop District, and about two-thirds of a mile from the lake front. This is

considered the smokiest section of Chicago, but the smoke in summer is much less dense than in winter. However, the fall of soot on the Federal Building was so considerable that on some days it was necessary to clean the photometer mirror after each series of readings.

The height of the dome was such that only an occasional tower or flag-pole obstructed the view of the horizon in any direction.

The remaining measurements were made from the top of a square tower connecting with Rosenwald Hall, University of Chicago. This tower is about 75 ft. high, one mile west of the lake, 3.5 miles southeast of the Union Stock Yards, and 5 miles northwest of the Pennsylvania Railroad Station in South Chicago. Light winds from either of these latter districts bring smoke over the University. At other times in summer the air is comparatively free from smoke, and on some days the sky is of a deep blue color nearly to the horizon.

The sky brightness measurements obtained at the University show little difference from the Washington measurements, except that the horizon is slightly darker, especially opposite the sun when the sky is clear. The measurements made at the Federal Building, however, show a decided darkening of the horizon opposite the sun. The zenith brightness, and the brightness in the region near the sun, is about equal to that shown on Figs. 2 to 13, incl., for Washington, but the color about the sun is a yellow-white, instead of a blue-white, as it is in a smoke-free atmosphere.

In order to show the effect of this darkening of the sky by smoke, I have computed the illumination on vertical surfaces facing 90° and 180° in azimuth from the sun, for both clear and cloudy skies, first for Washington, making use of the data in Figs. 10 to 13, inc., and then for Chicago from similar charts. The charts for Chicago were constructed from the mean of the measurements obtained at the Federal Building on eight cloudless half-days, with the sun 40° above the horizon, and from the measurements obtained with a cloudy sky on the morning of Aug. 1, with the sun at the same altitude. This was the only

half-day on which readings were obtained at the Federal Building with the sky completely covered with clouds. Table 4 gives the results.

TABLE 4. Illumination of Vertical Surfaces from Sky Brightness.

Place	Orientation of vertical surfaces					
	90° from sun			180° from sun		
	Washington	Chicago (Federal Building)		Washington	Chicago (Federal Building)	
	Ft-C.	Ft-C.	Ratio. c/w	Ft-C.	Ft-C.	Ratio. c/w
Illumination with clear sky	639	559	0.875	363	253	0.697
Illumination with cloudy sky	756	414	0.548	737	410	0.556

NOTE:—Ratio c/w=Ratio of Chicago Illumination to Washington Illumination.

TABLE 5. Means of Daylight Illumination Measurements.

Place	Solar altitude	Solar illumination		Sky illumination	
		Normal incidence	On horizontal surface	Normal to sun	On horizontal surface
	°	Ft. C.	Ft. C.	Ft. C.	Ft. C.
		Cloudless sky			
University	6	1220	205	545	339
University	22	5840	1850	1580	912
Federal B'l'g	23	3880	1260	1500	939
University	41	6410	4060	1960	1400
Federal B'l'g	41	6100	3440	2060	1300
University	60	7840	7130	2280	2000
Federal B'l'g	58	8380	7590	1530	1380
		Thin clouds			
University	20		508	1240	1180
Federal B'l'g	20	2260	1080		1054
University	40	4490	3600	2790	1860
Federal B'l'g	40	5520	3840	1620	1540
University	56	5840	5220	2740	2530
Federal B'l'g	58	4020	2270	3110	3250
		Partly cloudy sky			
University	20				878
Federal B'l'g	20				1171
University	40	4740	2500	1720	1470
Federal B'l'g	40		2310		2200
University	60	7620	6290	3380	3220
Federal B'l'g	60	7390	2820	3050	2820

It thus appears that vertical surfaces facing opposite the sun, in the Loop District of Chicago in summer, receive only two-thirds the daylight they would if the sky were free from smoke.

Table 5, which summarizes the illumination measurements on a horizontal surface, and on a surface normal to the sun's rays, shows unimportant departures from the Washington measurements except that the solar illumination measurements at the Federal Building are markedly lower, especially with low sun. It is hoped to repeat the Chicago measurements under winter conditions.

The utility of such measurements is clearly shown by the recent unpublished studies of Mr. A. Smirnoff, Statistician of the Potomac Electric Power Co., Washington, D. C., from which the following brief abstracts have been made with the consent of Mr. Smirnoff, and of Mr. R. B. Patterson, engineer for the company.

The District of Columbia has a double system of electrical supply: alternating current for the greater part of the residential section and direct current for the greater part of the business section. There is a comparatively small industrial load in the District, a condition favorable to a study of the relation between daylight and load.

It has been found that during the day in the business section a sudden increase in current consumption occurs when the daylight illumination intensity on a horizontal surface falls below 1500 ft.-c. The lower the intensity the higher the current consumption, but fluctuations in intensity above 1800 ft.-c. have only a neglible effect.

There are two general causes of decrease in daylight illumination: (1) decreased solar altitude, and (2) increased cloudiness.

With reference to (1), the time of day at which an intensity of 1500 ft.-c. is reached at different latitudes, when the sky is clear, has already been computed.[5] While we expect to increase the accuracy of these computed values, Mr. Smirnoff has already pointed out their present utility.

With reference to (2), the greatest interest attaches to the rapid diminution in daylight intensity in summer in connection with severe thunderstorms. On July 15th, of this year in Washington, shortly before 3 P. M., an unusually severe storm caused the daylight intensity to fall rapidly to something like 7 ft.-c.; and the sudden increase in load was probably one of the factors that put the electric power plant temporarily out of commission. The darkness lasted for about an hour.

In cities like Chicago, smoke in the atmosphere advances towards noon the time of occurrence of a deficiency in illumination due to (1), and greatly accentuates the deficiency due to (2) at all seasons of the year, but especially in winter, by an amount that may be computed when sufficient data have been obtained.

DISCUSSION

E. C. CRITTENDEN: In discussing the papers, it seems to be customary to compliment the speakers, and I think we can most certainly compliment Dr. Kimball and express our thanks for the contribution which he has made. Any of you who have had occasion to make measurements on daylight illumination under varying conditions of sky and cloud will know that the data presented must represent an immense amount of labor, and labor under conditions which are apt to be very discouraging, because it often looks as if you were not getting anything at the time.

Compiling these charts for a single day would be considerable of a job, but that would not be of particular value because averages must be obtained. For Washington Dr. Kimball has taken a sufficient number of days to get rather reliable indications of the average performance. Of course, as he has said, the data in Chicago, are preliminary data, based on a few days' measurements, but even these results are a valuable contribution to our knowledge of the subject. Any of you who have had occasion to deal with daylight conditions will recall, if you look through the TRANSACTIONS of the Society, that there is a small amount of defi-

[5]Kimball, Herbert H., Variations in the Total and Luminous Solar Radiation with Geographical Position in the United States, *Monthly Weather Review*, Nov. 1919, Vol., 47, charts 16-18, pp. 789-790.

nite information to be obtained, and this contribution is, therefore, of so much greater value because of filling a void of that kind.

In our discussion to-day, it has been repeatedly emphasized that the best artificial light is that which resembles most closely daylight, and much labor has been spent by manufacturers trying to make devices which will approach daylight in color and other properties. The Society might be reproached for the fact that we have paid so little attention to the effective use of the natural daylight, that the reasons for this condition are fairly obvious. Most of us are more concerned with the production of light, and the use of light thus produced, than with the use of daylight, and have been content to leave to others, such as the architects, the use of daylight.

However, as the recognized national organization dealing with lighting, we do have a considerable responsibility for encouraging the intelligent use of natural light. As some of the diagrams Dr. Kimball has shown have indicated, these problems are becoming more and more acute, as in our congested centers our buildings grow higher and our streets relatively narrower.

Our Committee on Lighting Legislation has felt compelled to make the requirements of its lighting code apply to natural lighting as well as to artificial lighting, and some codes already adopted, I believe, have attempted to correlate the requirements in factories with the conditions of sky brightness. In order to make such correlation more effective we must have more data than we have had previously, and these results of Dr. Kimball's will undoubtedly be of value in this connection. He has also indicated the probable value to power companies of being able to foresee a little in advance the possible rapid rises in demands for power resulting from the decrease of natural light.

The Society may well, therefore, lend its influence in helping to get togethre more of such data. I mention this particularly because as has been intimated, Dr. Kimball would like to go on to collect more complete and satisfactory data in Chicago and other industrial centers. He, as you know, is from the Weather Bureau; and the government, like every organization in these times, must require its agencies to show that the work they are doing is worth while. It is quite possible, therefore, that the influence of this Society in expressing an opinion regarding the

value of such work, may have considerable to do with determining whether this work can be accomplished. I do not know whether it is in order to offer any resolution in this meeting but such expression of our appreciation as can be given might be of real value to Dr. Kimball, not merely in showing our appreciation, but in helping him to go on with this valuable work.

E. L. NICHOLS: Mr. Chairman and Gentlemen, the measurements which the Chairman so kindly refers to are so different in scope from these systematic and far-reaching averages, these statistical measurements, that I do not know that I can contribute anything to this discussion.

I would only like to say that my observation consisted in simply running through the spectrum of the sky. My purpose on that occasion was not to secure average data at all, nor to secure absolute data, but to see whether the light reflected from the sky was appreciably modified by the light reflected back to the sky, from earth, and then from the sky to the surface of the earth again. That was the problem which I set myself on one of my long vacations. That is the reason why the measurements were made, some of them, at sea, some on the snow caps of the Alps, some on the Desert of Sahara, and some where I was surrounded by the green foliage and pastures of the Swiss Mountains.

It became evident, in the course of these observations, that the character of the surrounding soil and the greenness of the foliage did very materially affect the light received from the sky. But this, I take it, is not a problem which interests you as illuminating engineers to any great extent. You do not propose to paint all the roofs of the city of such a color as to modify daylight for the benefit of the inhabitants.

I would like to say, however, that the increasing brightness of illumination from the sky as cloudiness, increased up to a certain point at which there was a sudden collapse was very marked on a number of occasions, exactly corresponding with what was described in this paper. The same effect had also been described by some of the European observers a good deal earlier. Starting with sky measurements in the early afternoon, when a thunder storm was gathering, one would find the brightness increasing rapidly up to a certain definite point, and then suddenly dropping

off to a low value. That was a very common experience. I sometimes was so fascinated by this experience that I sat in the open, making measurements, until actually driven from the field by the downpour that followed. This growth of brightness occurs whenever there is a gathering of moisture in the afternoon, and it is apparent, in fact, quite apparent, before the cloud forms begin to be visible. You begin to notice it in the instrument before you are aware that the sky is clouding up. It is a very interesting phenomenon.

Commenting upon Mr. Crittenden's remarks that these things ought to be shown to be of practical value in order that they may have the backing and support necessary to continue them, I would like to say that there is a little peculiarity of the spectrum of the sky which I noted in the course of these measurements on such days as that which I have spoken of, where a thunder storm was gathering, and where there was generally more or less violent disturbance toward sunset, in which I was very much interested and about which I was considerably skeptical myself; so much so that I hesitated very much to publish the curves. I finally put them into the papers which I afterwards published on this subject, with considerable reservation in my own mind and hardly expected that they would be generally accepted. The phenomenon consisted of marked absorption of blue and violet, so that you have a crook in the curve showing a certain absorption band, out near the end of the visible spectrum. That was something which began along about noon on certain days especially in the mountain climates, and increased steadily up to the time when showers occurred. It was also visible at times when the actual showers did not come, but it was indicative of certain types of weather. I had pretty nearly forgotten about the effect myself when Pacini, who made many measurements of the sky, in Italy, repeated and confirmed that particular peculiarity of the spectrum. He indicated in his papers that studies of sky spectra, might be used for short time forecasting of what was going to happen later that day. When this developement occurs in the forenoon, you can pretty well predict what that afternoon in going to furnish in the way of weather.

I don't suppose that our weather bureau will take up anything of that kind, but I wish to point out that little peculiarities which

the observer finds and does not see any particular bearing or meaning to, may ultimately be of some practical importance.

There is one other thing I wanted to say for the benefit of some who may have had my data and who, discarded them because they failed to match similar measurements which were being made in this country. The skies which I measured in the course of the summer, of 1906-07, did not at all correspond, as regards the blueness of the daylight, with what other observers were getting. The discrepancy was very serious and could not be explained at the time but it was explained shortly afterwards by one of the meteorologists in the Weather Bureau at Hamburg, namely: that during that particular season on the continent of Europe there had been a vast amount of volcanic dust in the air. It gave a yellowish cast to the daylight all through that year.

LOUIS BELL: May I just add to the very interesting remarks of Dr. Nichols that a few years ago I was examining the polariscopic phenomena of the sky and observed rather a strong correlation between the polarization of the sky and what might come after it. I was observing in a mountain country with a Savart polariscope and time after time, during the weeks I was observing, when I was searching around, looking over various parts of the sky, far down the valley I could pick up strong polarization of the sky. In the course of a few hours, the wind coming up the valley would bring something that was very noticeable in the way of weather. One could descry, out on the horizon, looking through a good many miles of atmosphere, the gathering nucleation of the air that showed polarization first and afterwards resulted in sudden change in the weather.

I think the polariscope is not a general solvent of meteorological difficulties but certainly it shows local conditions of the atmosphere in a very striking way, local conditions that may have considerable bearing on what happens in the next six or twelve hours.

F. C. CALDWELL: As you know, one of the problems of our university men is getting subjects for investigation or research for the students. It occurred to me that possibly this work of Dr. Kimball's might be useful to us in that way. We might be useful to Dr. Kimball in his movement. I am wondering whether

there might be a phase of this that could be advantageously taken up at different points of the country, in connection with the student's research work, and continued from year to year.

I might say that the Committee on Education of the Society has had in mind this matter of suggesting research subjects to the various educational institutions who are interested in the work of our Society.

A. L. POWELL: I have had the experience common to most of us of searching for data on daylight intensities and being disappointed in the dearth of good material. I wish to express further personal appreciation of Dr. Kimball's paper and for the wealth of information he has given us.

I experienced a rather amusing coincidence last summer. Returning to the office one day after lunch, I noticed that an extremely high intensity seemed to prevail. We immediately made some measurements with two photometers on the roof of one of the buildings at Harrison, N. J. and found an average value of 11,600 foot-candles. On returning to the office I chanced to glance at the calendar and noted that it was June 20 and my watch showed slightly after one o'clock daylight saving time. Thus we happened to obtain a reading at noon on the day with the sun at its highest elevation.

F. E. CADY: Like the previous speakers I cannot help expressing my admiration for the amount of work that is represented by these data. Anybody who is conversant with photometric procedure and knows the labor involved even in the simplest measurements will appreciate what these figures must mean in the time and effort required both in their acquisition and preparation.

There are two features of the paper which I should like to comment on. In the first place, I would call attention to the actual magnitude of the figures in Table I, giving the illumination produced by sunlight, running as high as 9,000 foot candles. I refer to this because some years ago I attempted to produce artificially in a sheltered spot the same illumination as that on an adjoining spot exposed to full sunlight. At that time, I measured the illumination desired and found it in the neighborhood of 9,000 foot candles. By using a concentrated filament

high candlepower lamp in a concentrating reflector and not far from the ground. I was able to reach this illumination but only over a relatively small area. This brought home to me more vividly than ever before the relatively enormous illumination values which we encounter out of doors in ordinary summer weather.

And this brings me to the second point which the paper illustrates indirectly, and that is the marvelous adaptability of the eye whereby we are enabled to pass from the high illuminations outdoors to the five or ten foot-candle values indoors and still be able to see clearly and distinctly.

H. H. Kimball: (In reply,) I think not much needs to be said in closing. Dr. Nichols refers to the reflection from clouds, and the increase in illumination as a thunderstorm is gathering. We have published some beautiful automatic records,[1] and I wish that you might see them. As a cloud approaches the sun there is intense reflection from it, and if the sky is still clear above the sun, this reflected light is added to that already being received from the sun and sky. This increase sometimes amounts to as much as fifteen or twenty per cent, and in winter to even fifty per cent.

I am wondering how much atmospheric absorption had to do with those bands he refers to. We know that the atmosphere absorbs in certain spectrum bands. I am not certain that this band of his corresponds to any of the atmospheric absorption bands. In Washington we make a great many measurements of solar radiation intensity in heat units. If on a clear morning there is intense atmospheric absorption and the heat measurements are low, we usually predict that at a certain time cumulus clouds will form, and we are able to approximate the time rather accurately.

With regard to Dr. Bell's comment on a relation between the polarization of skylight and the weather, such a relation has been noticed. We make polarization measurements on every clear day at the point of maximum polarization, which is about ninety degrees from the sun, and in his vertical. The polarization of the skylight does not vary much with the amount of moisture in

[1]Kimball, H. H., and Miller, E. R., The Influence of Clouds on the Distribution of Solar Radiation. Bulletin Mt. Weather Obsy. Vol. 5, p. 166-172.

the atmosphere, but does vary with the dustiness or haziness of the atmosphere. When insipient condensation sets in, forming water drops, the polorization is greatly diminished. If on a clear morning the percentage of polarization of skylight is low we have learned to expect a cloud sheet before night. The forecasters have not been able to use these observations in any systematic way, however.

One of the speakers refers to the brightest time of the year, and sets that time as the 20th of June. I would beg to differ with the speaker. There are two or three reasons why we should not expect the 20th day of June to be the brightest day. First, because the sun is then at nearly its maximum distance from the earth. The variation in the sun's brightness due to variation in distance from the earth is about seven per cent. Second, the moisture content of the atmosphere has a marked influence upon the brightness of the sun. The moisture content in June, while not as great as in August or July, is much greater than in April or May; and the greatest solar radiation intensity that we have ever measured in Washington was in the month of April, not in June.

Mr. Cady referred to the wonderful adaptibility of the eye to different light intensities. We have found by experiment that one is able to read coarse print by moonlight, which has an intensity of about two one-hundredths of a foot-candle, and to carry on outdoor occupations, such as driving, when the illumination is only about four-tenths of a foot-candle. We are also able to work without much trouble at high noon in summer, when the illumination approaches 10,000 foot-candles. In this latter case, however, we do shield our eyes from the direct light of the sun.

Replying to Prof. Caldwell. There is every opportunity for co-operation in sky brightness measurements by educational institutions. Any institution that has a photometer can make measurements that will be of value in this research. If it has a spectro-photometer, the measurements will be of special value since we have not yet been able to measure daylight qualitatively in a systematic way. Such measurements would be of special interest, and I think are such as students can well make.

C. F. Scott: In view of the relative importance of sunlight as compared with artificial light to which our attention is directed, and in view of the fact that the Government department is making these investigations, I move that the question of an expression on the part of the Society to the Weather Bureau in connection with matters of this kind, be referred to the Council of the Society for consideration.

(The motion was seconded by Dr. Bell and referred by the Convention to the Council of the Society.)

INCANDESCENT LAMP TEMPERATURES AS RELATED TO MODERN LIGHTING PRACTICE*

BY CHESTER L. DOWS AND WILLARD C. BROWN.**

Operating temperatures of incandescent lamps, both bare and in the numerous types of reflecting and diffusing equipments offered for use with them, have been the subject of much discussion, particularly since the introduction of the gas-filled lamp. Occasionally a poorly designed lighting unit has been placed upon the market, with the result that trouble has been experienced with one or more of its various parts due to high temperature. Then, too, the interpretation of the various sections of the National Electrical Code pertaining to lighting unit temperatures has been the source of much conflict of opinion. The determination of what temperatures are permissible, and what temperatures are positively dangerous under various conditions of operation is also a much debated question. The effect of ventilation in a lighting unit is a favorite point for argument.

This paper, which is based upon experimental work carried on over a period of years, is intended to clear up many questions on the operating temperatures of incandescent lamps which have heretofore been in doubt. The material presented is divided into four main parts:

First—Temperatures of incandescent lamps operated without reflecting and diffusing equipments;

Second—Temperatures of incandescent lamps operated with reflecting or diffusing equipments;

Third—Ventilation vs. non-ventilation;

Fourth—Suggestions on the use of incandescent lamps in interiors which present special temperature problems.

*A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

**Engineering Department. National Lamp Works of General Electric Co., Cleveland, Ohio.

PART I—TEMPERATURES OF INCANDESCENT LAMPS OPERATED WITHOUT REFLECTING OR DIFFUSING EQUIPMENT.

FILAMENT TEMPERATURES.

The incandescent lamp emits light by virtue of the fact that it contains a filament which is operating at a temperature sufficient to make it incandescent. The temperature at which the lamp filament may safely be operated depends, among other things, upon the material of which it is composed. The melting point of tungsten is 6156 degrees Fahrenheit (3675° Kelvin). Contrary to the popular opinion, the relatively high temperature at which tungsten filament can be operated is possible not alone

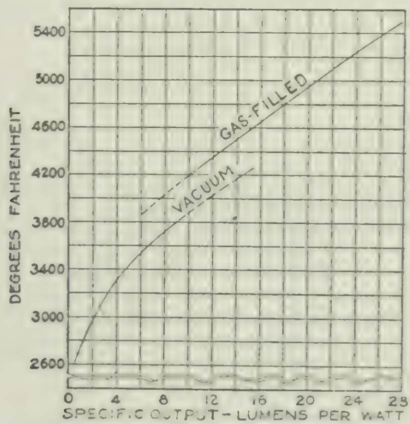


Fig. 1.—Relation of filament temperature to lumens per watt.

because of its high melting point but also because of its ability to resist disintegration when heated to incandescence. The use of an inert gas within the bulb, cutting down the rate of filament evaporation, together with a coiled filament, giving the effect of a much larger filament wire, permits a materially higher operating temperature in the gas-filled than is possible in the vacuum lamp.

Figure 1 shows graphically the relation between the filament temperatures and specific output in lumens per watt for the vacuum and gas-filled lamps.

Table 1 compares the filament temperatures of the plain carbon, metallized carbon, vacuum tungsten and gas-filled tungsten lamps. It will be noted that the gas-filled lamps, particularly those of higher efficiency, operate at filament temperatures considerably higher than those of the vacuum lamps.

TABLE No. 1—Filament Temperatures of Incandescent Lamps*

Lamp	Approximate lumens per watt	Approximate filament temperature Deg. F.
50-watt Carbon	3.3	3350
50-watt Gem	4.1	3470
50-watt Tantalum	4.9	3430
40-watt Vacuum	9.9	3860
100-watt Gas-filled	12.6	4370
200-watt Gas-filled	15.5	4600
500-watt Gas-filled	17.4	4750
1000-watt Gas-filled	19.6	4910
1000-watt Gas-filled (Stereopticon)	24.1	5250
900-watt Gas-filled (Motion picture)	26.2	5390

ENERGY DISTRIBUTION IN TUNGSTEN LAMPS.

Observations will show that the air in the vicinity of an unshielded, uncovered gas-filled lamp is hotter than that near a vacuum lamp of equal wattage.

The principal cause of this difference in local temperatures is, essentially, that the gas content of the lamp is not only a conductor of heat but allows heat convection to the bulb surface; the relatively high vacuum within the bulb of the other lamp permits of little or no heat conduction or convection.

The approximate relative distribution of energy within a 100-watt vacuum and a 100-watt gas-filled lamp is given in Table 2; a graphical presentation of these data appears in Fig. 2. It is seen that the energy expended in local heating in the case of the gas-filled lamp is greater than in that of the vacuum lamp in ap-

*Journal of Franklin Institute, Vol. 192, p. 109, 1921.

proximately the ratio of 3 to 1. This greater local heating causes higher operating temperatures on the bulb surface, at the base of the bulb, in the socket and lead-in wires, and upon the surface of the reflecting equipment within which the lamp may be burned.

TABLE No. 2. – Distribution of Energy within 100-watt Tungsten Lamps

	Vacuum Per cent of total energy	Gas filled Per cent of total energy
Heat lost through gas in bulb (conduction and convection)	0	20
Heat lost through lead-in wires and supports (conduction)	8	5
Heat radiation	86	67
Light radiation	6	8
	100%	100%
Total local heating	8	25
Total radiation	92	75
	100%	100%

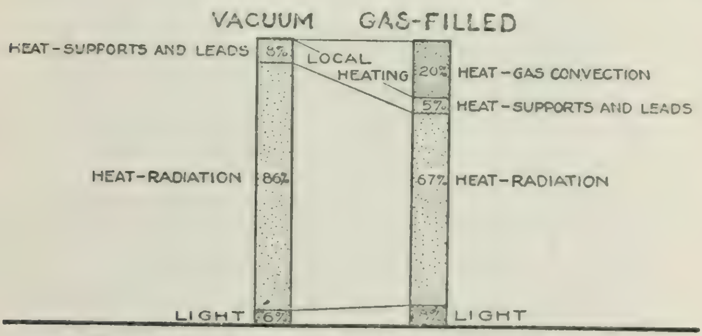


Fig. 2.—Distribution of energy within 100-watt lamps.

EFFECTS OF EXCESSIVE TEMPERATURES ON LAMPS AND ACCESSORIES

With the standards of lamp design and manufacture in their present state of advancement, operating troubles due to the higher temperatures of gas-filled lamps are rarely encountered. It is only in extreme conditions of improper usage that serious difficulties are likely to arise. Experience has shown that, almost invariably, such difficulties are the result of unusual practices or

combinations of outside influences which either through negligence or ignorance are allowed to persist. The principal effects of excessive operating temperatures with corrective measures taken to avoid them are here enumerated and briefly discussed.

BLISTERING OF THE BULB.

Blistered bulb is caused by the glass softening under high temperature, a bubble being formed on the bulb from the pressure of the gas within. The glass used for bulbs in the regular vacuum and gas-filled lamps will soften if subjected to excessive temperature. There appears to be no definite bulb temperature below which it is safe to assume that the glass will not soften or above which it can be stated that a blister will be formed. The temperature at which softening occurs depends upon too many variables, such as the particular melt of glass in question, the thickness at the point considered, the position of burning of the bulb, etc. When the bulb is operated tip up or in a horizontal position, a blister may occur at the top, or on the bowl of the bulb above the filament, at temperatures which would produce no harmful effect if obtaining at the neck of the bulb when operated tip down. A higher temperature is usually required at the neck to produce a blister when the lamp is operated tip down than is required for a blister at the tip with the same lamp operated tip up. A very general figure for the region where ordinary bulb glass has been found to soften would be 600° F.

From the point of view of local heating, it is preferable to operate the lamp tip down, except where the lamp is designed for tip-up operation. The hot gases always rise to the top regardless of the position of operating and the shape of the bulb, with its tapering neck and, in large sizes, mica disc, is designed to take care of the heat when operated tip down. When tip-down lamps are operated tip-up, for example, the location of the maximum temperature zone is shifted to the tip, and the temperature here is some thirty per cent higher than that found at the neck (maximum temperature zone) with the lamp operated tip down.

Where exceedingly high temperatures are to be met with, as, for example, in the gas-filled motion picture lamps, the bulb is made of a different glass. The softening temperature of this glass is very much higher than that of the ordinary glass. This

allows the bulb to withstand the much higher temperatures with reasonable safety.

LOOSENING OF THE BASE.

The temperature at which the basing cement will soften and allow the bulb to loosen at its base depends upon many factors, and it will be difficult to attempt to fix any definite critical value. The point considered for measurement of operating temperatures here is the junction of the brass and the glass of the bulb. Cases of loose base have occured frequently where the temperature of this point exceeded 400° F. In well designed units, however, the operating temperature at this point is considerably below this figure and therefore is well within safe limits.

MELTING OF THE SOLDER.

A high operating temperature may in extreme cases cause softening of the solder used to secure the lead-in wires to the base. Since the melting point of solder is dependent upon its composition, the kind of solder used determines the danger point for it. A curve showing the melting points of different compositions of solder will be found in the Appendix, Fig. 7. Trouble of this kind was encountered in the early development of the high-current motion picture lamp. Due to an imperfect base contact in the socket, excessive heat may be developed. A welding process has been developed, however, whereby the lead-in wires are welded to the base. This does away with any danger of the connection at this point loosening during operation either from high surrounding temperature or poor contact.

DETERIORATION OF WIRING NEAR THE SOCKET.

The Underwriter's National Electrical Code states that slow-burning wire shall be used in a fixture or unit where the temperature of the wire is in excess of 120 degrees Fahrenheit. This temperature is sometimes exceeded in practice, even in units of comparatively low wattage. Careful design of a unit will, however, materially lower the wire temperature.

Both the mechanical and electrical properties should be considered when investigating the durability of insulation, especially when temperature is involved. There seems to be no exact relation between the dielectric insulating quality of rubber wire

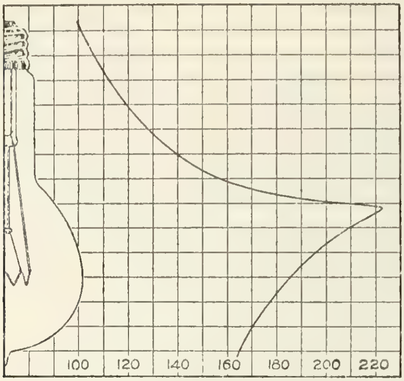


Fig. 3.—Temperature gradient on bulb for 100-watt gas-filled lamp by change of resistance method.

insulation and the time that it has been subjected to a certain temperature. When weak spots appear, they do so at irregular intervals.

DETERIORATION OF SOCKET PARTS

There has been considerable discussion as to the heat resisting qualities of the standard brass shell socket, having a lining of impregnated paper. From a temperature standpoint, the weakest element in a key socket is the composition forming the key although excessive temperature may also cause charring of the paper insulating shell, and softening of the wax used to cover the screw heads. Extensive tests conducted on brass shell sockets equipped with various types of shades and reflectors, with the household sizes of gas-filled lamps, indicate that it is practically impossible to push the operating temperatures of the various points of the socket high enough to cause physical damage to the socket. Even with the most unfavorable design of shade or reflector, from the standpoint of heat, the operating temperatures of the vulnerable parts of the socket are within the limits of safety.

The 1918 edition of the National Electrical Code contained the following clause:—"Gas-filled incandescent lamps—if of above 100 watts, must not, if provided with a shade, reflector, fixture or other enclosure above the socket, be used in either medium or mogul base types of sockets or receptacles having

fibre or paper linings." This provision has been eliminated in the present (1920) edition of the Code.

BULB TEMPERATURE DATA.

In obtaining temperature data, as in taking other measurements on incandescent lamps, it is necessary to consider the average of several tests, for the operating temperatures of lamps of the same wattage and type differ somewhat on account of manufacturing variations in thickness of the glass, gas pressure within the bulb, temperature and humidity of the surrounding atmosphere, etc. Lamps of a given wattage and type will generally agree within 8 per cent at the same point of measurement.

Table 3 gives representative operating temperatures of various tungsten lamps, operated bare, tip down, in a room at ordinary temperature. The values given are the averages for several tests. The lamps were in each case operated at rated wattage.

EFFECT OF BULB BLACKENING UPON BULB TEMPERATURES.

There is some rise in the bulb temperature of a lamp as it

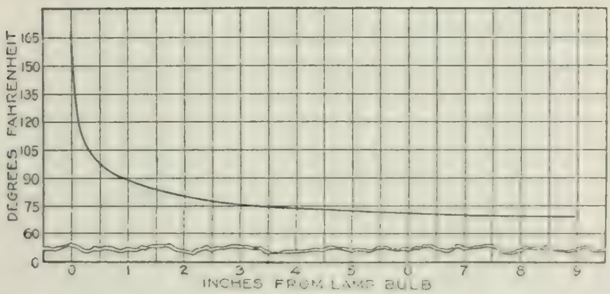


Fig. 4.—Temperature gradient in air for 100-watt gas-filled lamp (measurements taken opposite filament) by thermometer method.

becomes blackened during the latter portion of its life. As the bulb discolors, more radiant energy is absorbed by the glass at the bulb surface, and the temperature at that point rises.

When operated tip down, the blackening occurs about the neck; when operated tip up, blackening occurs at the tip. In either case, the increase in temperature due to bulb discoloration, is most noticeable in the maximum temperature zone.

Tests have shown that the rise in bulb temperature in a considerably blackened bulb after 1,000 hours of operation is of the general magnitude 8 per cent.

TABLE No. 3—Operating Temperatures of Tungsten Lamps

Types of lamp*	Bulb size	Temperature of bulb (Maximum) Deg. F.	Temperature of bulb opposite filament Deg. F.	Temperature of bulb at junction of brass & glass Deg. F.
50-watt Vacuum	S-19	153	153	113
50-watt White	PS-20	262	188	189
75-watt Gas-filled	PS-22	240	175	181
100-watt Gas-filled	PS-25	262	179	183
150-watt Gas-filled	PS-25	338	210	150
200-watt Gas-filled	PS-30	330	212	171
300-watt Gas-filled	PS-35	297	226	175
500-watt Gas-filled	PS-40	379	288	196
1000-watt Gas-filled	PS-52	371	243	165
75-watt Daylight	PS-22	329	262	222
100-watt Daylight	PS-25	320	247	192
150-watt Daylight	PS-25	379	309	176
200-watt Daylight	PS-30	339	294	179
300-watt Daylight	PS-35	385	315	198
500-watt Daylight	PS-40	424	363	218
1000-watt Ph'gr'ic	PS-52	363	334	318
1500-watt Ph'gr'ic	PS-52	541	474	269

*Lamps above 200 watts are fitted with mogul screw bases,

EFFECT OF VOLTAGE UPON OPERATING TEMPERATURES.

The temperature of a gas-filled lamp at any point depends upon the voltage impressed upon the lamp. If this voltage is increased, so is the temperature of all points of the bulb increased, and vice versa. The temperature, however, does not increase or decrease so rapidly as does the voltage.

A thorough investigation has been carried out to determine the exact relation between voltage and operating temperature at the three points at which the operating temperatures are ordinarily considered. The curves of Fig. 5 show the variation

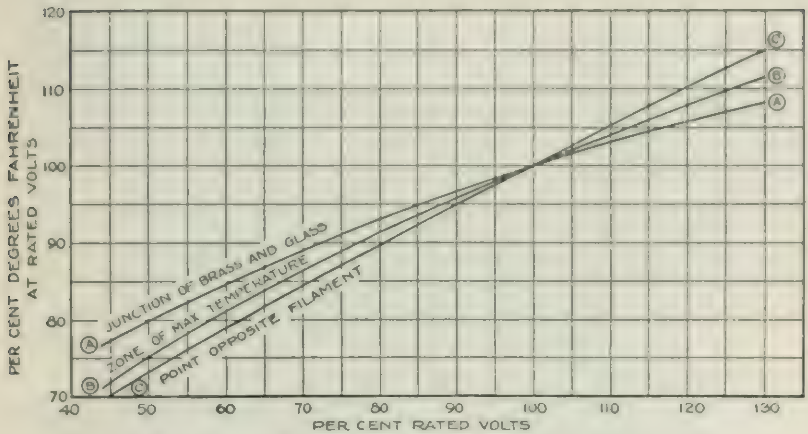


Fig. 5.—Variation of Temperature with voltage for gas-filled lamps.

of temperature with voltage for gas-filled lamps (See Appendix, for Exponential Equations).

PART II—TEMPERATURES OF INCANDESCENT LAMPS OPERATED WITH REFLECTING AND DIFFUSING EQUIPMENT.

The 1920 National Electrical Code states that gas-filled lamps must be equipped so that any exposed surfaces of a unit which might come in contact with inflammable material will not have a dangerous rise in temperature. Fortunately, ample protection in this respect is afforded by the equipments which are used to redirect and diffuse the light.

For the purpose of considering their operating temperatures, the various types of lighting equipment have been grouped as follows:

1—Enclosed units of the type in common use in ordinary interior lighting;

2—Open reflectors of the type in common use in ordinary interior lighting;

3—Silk shades;

4—Vapor-proof units;

5—Street-lighting units;

6—Flood-lighting units;

7—Motion picture and stereopticon machines.

ENCLOSED UNITS.

In Table 4 are shown typical units, with corresponding comparative data, which fall within this group. It should be noted that the lamp in this type of equipment is either totally enclosed or nearly so.

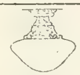
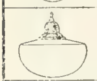
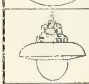
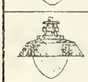
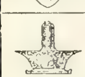
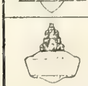
UNIT	LAMP	DEGREES FAHRENHEIT			
		TEMPERATURE OF BULB (MAXIMUM)	TEMPERATURE OF WIRE IN CONDUIT	TEMPERATURE OF BULB OPPOSITE FILAMENT	TEMPERATURE OF BULB AT JUNCTION OF BRASS AND GLASS
	200-WATT DAYLIGHT	492	168	394	258
	500-WATT DAYLIGHT	542	240	438	356
	200-WATT DAYLIGHT	365	155	345	226
	200-WATT GAS-FILLED	392	140	284	231
	300-WATT GAS-FILLED	385	178	298	228
	1000-WATT GAS-FILLED	569	174	474	348
	200-WATT GAS-FILLED	324	142	284	238
	300-WATT DAYLIGHT	458	164	393	278
	500-WATT GAS-FILLED	530	147	494	343
	300-WATT DAYLIGHT	424	165	376	292

Table No. 4.—Operating temperatures of various enclosed units.

Enclosed units are, of course, manufactured in many styles and designs, in some of which provision is made for ventilation. It has long been assumed that ventilation in a unit of this type necessarily results in lower operating temperatures of all its parts. This assumption, however, is not borne out by fact. In

many cases it is found that units designed for operating without ventilation actually run hotter at vital points when provided with openings for ventilation. The important point to be remembered in the design of non-ventilated units is that the heat must be dissipated principally by radiation. If ample radiating surface is provided, heat is effectively dissipated in all directions. Tests on a number of units indicate that, as a rule, the wire and socket parts of a well-designed non-ventilated unit actually run cooler than when the unit is ventilated by any one of the standard methods, and that the lamp bulb and surrounding glassware are raised slightly in consequence.

The increase in wire temperature because of ventilation is generally due to the fact that ventilating holes direct the flow of heated air in such a manner that it strikes the reflector cap or conduit, or flows upward along their surfaces. It appears that about the only types of units in which ventilation lowers the wire temperature are those having a holder of relatively large diameter, with the ventilating spaces in the holder so arranged that the heated air is directed out away from the holder and not allowed to flow along its outer surface.

Ventilating an enclosed unit does in most cases lower the bulb temperatures. In a well-designed unit, however, whether ventilated or not, the bulb operating temperatures are well within safe limits for satisfactory operation. The wire is usually the point at which greatest attention is directed, since in the case of a unit taking a lamp with a medium-screw base, rubber-covered wire is allowed by the Electrical Code only when the temperature of the wire does not exceed 120° F.

A completely enclosed unit may be made dust and bug proof, thus gaining a distinct advantage from the standpoint of maintenance; usually, also, the absence of holes and other openings results in improved appearance.

OPEN REFLECTORS.

The operating temperatures of three representative units of this group are shown in Table 5.

The bulb temperatures of a lamp operating in an open reflector are usually well within safe limits whether the holder or

upper part of the reflector is ventilated or not. The wire temperature, however, is of importance. Here again rubber-covered wire is allowed by the National Electrical Code, provided the wire temperature does not exceed 120° F. Hence, many reflectors are provided with ventilating openings with the assumption that they lower the wire temperature. These openings sometimes consist merely of holes drilled through the upper portions of the reflector; in other cases, an elaborately designed holder is furnished with numerous channels and slots for the flow of air.

In general, tests show that the wire temperature in an open reflector is little affected by ventilation. In some cases it is lowered a matter of one or two per cent; in others, it is not changed when the reflector is ventilated; and, not infrequently, it is actually raised slightly when ventilation is provided and the heated air allowed to flow upward to the cap or conduit.

The circulation of air about the lamp bulb and interior

UNIT	LAMP	DEGREES FAHRENHEIT			
		TEMPERATURE OF BULB (MAXIMUM)	TEMPERATURE OF WIRE IN CONDUIT	TEMPERATURE OF BULB OPPOSITE FILAMENT	TEMPERATURE OF BULB AT JUNCTION OF BRASS AND GLASS
	200-WATT GAS-FILLED	347	125	236	211
	200-WATT GAS-FILLED	398	130	294	252
	50-WATT WHITE	289	141	208	209

Table No. 5.—Operating temperatures of open reflectors.

surfaces of the reflector accelerates the accumulation of dust, lint, and other fine particles in the air and makes more frequent cleaning necessary.

SILK SHADES.

Silk is used in many cases as a material for lamp shades, particularly in the home. Where these shades do not come in direct contact with the lamp bulb, no discoloration of the cloth will occur with the ordinary household sizes of vacuum and gas-filled lamps. However, owing to the high operating temperatures

of the bulb surface, charring may occur where draperies, silks, etc., become closely wrapped about the bulb.

In this connection is should be stated that even a vacuum lamp, if completely wrapped about with dark silk or similar material, so that a very large proportion of the radiant energy is confined, will actually start a fire. It is only in such extreme cases that trouble is experienced in the use of cloth as a shade material.

VAPOR-PROOF UNITS.

In this type of unit, the lamp is completely enclosed in a protective covering of glass and metal. Ordinarily, washers or gaskets are used at the various joints between casing, globe, etc., to provide an absolutely air-tight housing for the lamp.

UNIT	LAMP	DEGREES FAHRENHEIT			
		TEMPERATURE OF BULB (MAXIMUM)	TEMPERATURE OF WIRE IN CONDUIT	TEMPERATURE OF BULB OPPOSITE FILAMENT	TEMPERATURE OF BULB AT JUNCTION OF BRASS AND GLASS
	200-WATT GAS-FILLED DAYLIGHT	463 531	158 174	426 526	258 314
	500-WATT GAS-FILLED DAYLIGHT	580 587	183 214	569 578	319 329
	200-WATT GAS-FILLED	418	162	311	261
	150-WATT GAS-FILLED DAYLIGHT	413 503	129 136	333 456	253 258
	75-WATT GAS-FILLED DAYLIGHT	307 382	110 126	232 312	225 247

Table No. 6.—Operating temperatures of vapor-proof units.

The operating temperatures for various units of this type are given in Table 6.

The vapor-proof unit is used where it would be impracticable or inadvisable to use an unprotected or even partially protected lamp. It is designed to protect against explosive vapors, or acid fumes which might attack the bulb surface, and to prevent explosive or combustible dusts from coming in contact with the hot

bulb. Its greater mechanical strength minimizes the chance of physical damage to the unit exposing the hot filament in explosive atmospheres.

The very nature of a vapor-proof unit precludes the possibility of ventilation. The globe is usually of very heavy glassware as compared with the ordinary enclosed unit. Also, for greater mechanical strength the metal portions of the unit often consist of castings instead of light spinnings.

The air spaces about the lamp in a vapor-proof unit are in general smaller than in an enclosed unit of the same wattage. This, together with the heavy, thick globe results in higher bulb operating temperatures.

Since the vapor-proof unit is particularly designed for use where explosive vapors or dusts are present in the air, the maxi-

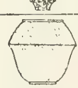
UNIT	LAMP	DEGREES FAHRENHEIT				
		TEMPERATURE OF BULB (MAXIMUM)	TEMPERATURE OF WIRE IN CONDUIT	TEMPERATURE OF BULB OPPOSITE FILAMENT	TEMPERATURE OF BULB AT JUNCTION OF BRASS AND GLASS	TEMPERATURE OF BULB AT TIP
	100-C.P. 6.6 AMPERES GAS-FILLED	——	——	202	104	428
	100-C.P. 6.6 AMPERES GAS-FILLED	——	——	199	103	425
	500-WATT GAS-FILLED	347	127	456	201	543
	500-WATT GAS-FILLED	496	307	436	370	——

Table No. 7.—Operating temperatures of street-lighting units.

mum temperature on the outer surface of the unit is of the utmost importance.

In testing vapor-proof units, it has been noted that in some cases gaskets or washers of a rubber composition with a relatively low softening point, have been used to seal the joints. In several instances, the temperature was sufficient to soften and melt these washers. The molten composition then flowed or dripped down over the lamp and the inside of the globe, giving an extremely unsightly appearance. Furthermore, when the globe

was removed to replace a lamp, new washers had to be inserted if vapor-tight joints were to be maintained. The temperature which such washers must withstand depends largely upon their location within the unit. In all cases they should be designed to stand up under long-continued operation with the largest size of lamp that can be used in the unit.

STREET LIGHTING UNITS.

Operating temperatures of a few representative types of street-lighting units are given in Table 7.

Gas-filled series lamps are commonly used in street-lighting units, although multiple lamps are also used to some extent. In

UNIT	LAMP	DEGREES FAHRENHEIT			
		TEMPERATURE OF BULB (MAXIMUM)	TEMPERATURE OF BULB (OPPOSITE FILAMENT)	TEMPERATURE OF REFLECTING SURFACE	
				MAXIMUM	AVERAGE
 ALUMINUM REFLECTOR	400-WATT GAS-FILLED G-40 BULB	692	389	159	139
 SILVERED GLASS REFLECTOR	400-WATT GAS-FILLED G-40 BULB	687	390	185	160
 SILVERED BRASS REFLECTOR	400-WATT GAS-FILLED G-40 BULB	678	408	218	192
 SILVERED GLASS REFLECTOR	500-WATT GAS-FILLED PS-40 BULB	491	466	310	270

Table No. 8.—Operating temperatures of flood-lighting units.

this service, the lamps are not infrequently operated tip up and the temperature near the tip of the bulb is, in such cases, an important consideration. If this part of the lamp runs too hot, a blister is formed on the bulb.

In some street-lighting units, an attempt is made to cool the bulb by providing ventilating openings at the top of the globe. These vents are protected in most cases by a cap with suitable

openings for the flow of air. Where the unit is completely closed at the bottom, as is the case in units mounted directly on standards, ventilation at the top usually has little effect upon the bulb operating temperatures and may well be dispensed with. In a pendant type of unit with the lamp operated tip down, ventilation will usually result in lowering the bulb temperatures.

The wire temperature is higher in units in which the lamp is operated tip down than in those in which the lamp is operated tip up; in either case, however, wire temperature is usually of little moment.

In street lighting, where maintenance is such an important item in the operation of the system, the advantages of a properly designed non-ventilated unit are especially important.

FLOOD-LIGHTING UNITS.

The operating temperatures of several typical flood-lighting units are given in Table 8. When operated horizontally, the lamp is seldom ventilated although when operated tip down, ventilation is sometimes provided by means of a small opening about the lamp neck. The cover-glass, which protects the unit from the weather, tends to confine the heat.

In the majority of flood-lighting equipments, the lamp is operated either tip down or in a horizontal position. More difficulty would naturally be expected from bulbs blistering in lamps operating horizontally than in those operating in a tip-down position. However, since the lamps for this service are regularly constructed of a heat-resisting glass, this trouble is not common.

Ordinarily, the reflecting surface of a flood-lighting unit contains silver in some form, and because of its tendency to discolor at high temperatures, a study of its operating temperatures is important.

MOTION PICTURE AND STEREOPTICON MACHINES.

In motion picture and stereopticon service, the lamp is usually operated tip up. Tubular bulbs are standard for motion picture service and for many slide projectors. For these latter equipments, they are replacing the round bulb lamps which were long used for the projection of slides but which are not adapted to the optical systems used in motion picture projection.

The lamp is operated within a housing, usually of metal. This housing ordinarily contains a spherical mirror, used to redirect to the condenser lens the light which would otherwise be lost at the rear portions of the housing. Often the condenser lens is secured in or upon a frame extending from the housing. In the larger motion picture projectors, the lamp housing is separate from the aperture plate and necessary film driving apparatus, shutters, etc. In the small portable projectors, such as the "suit case" types, the housing is often mounted within the case containing the driving apparatus, reel holders, etc. Most housings are well ventilated to carry away the heat from the lamp and thereby reduce the bulb and housing temperatures.

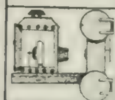
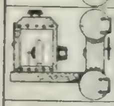
UNIT	LAMP SIZE	LAMP OVERALL LENGTH		DEGREES FAHRENHEIT: TEMPERATURE OF BULB AT TIP	DEGREES FAHRENHEIT: TEMPERATURE OF BULB OPPOSITE FILAMENT	DEGREES FAHRENHEIT: TEMPERATURE OF BULB AT [illegible] OF BRASS [illegible]
	900-WATT GAS-FILLED T-20 BULB	$9\frac{1}{2}''$	LAMP WITHOUT HOUSING	742	753	386
			LAMP IN HOUSING	810	978	445
	400-WATT GAS-FILLED T-20 BULB	$5\frac{1}{2}''$	LAMP WITHOUT HOUSING	636	464	275
			LAMP IN HOUSING	769	648	406
	1000-WATT GAS-FILLED T-20 BULB	$9\frac{1}{2}''$	LAMP WITHOUT HOUSING	820	751	336
			LAMP IN HOUSING	906	914	458
	400 WATT GAS-FILLED T-20 BULB	$5\frac{1}{2}''$	LAMP WITHOUT HOUSING	636	464	275
			LAMP IN HOUSING	713	638	367

Table No. 9.—Operating temperatures of motion picture and stereopticon units.

Table 9 gives representative operating temperatures taken in several motion picture and stereopticon housings.

In addition to the usual points on the bulb, there are other parts of a motion picture housing which require attention. The temperature of the condenser lens is important. The operating temperature of the spherical mirror should be kept below the region where rapid deterioration of its reflecting surface takes place. The temperatures of the outer portions of the housing are of importance particularly where the standard inflammable

film is used. Any portions of the housing with which the film is liable to come in contact, due to any cause, should not be at a temperature sufficient to cause ignition. In this connection the following data are of interest:

Results of test on standard inflammable film

Curls at	172° F.
Emulsion melts at	320° F.
Ignites at	365° F.

Obviously a temperature approaching 365 degrees Fahrenheit at any portion of the housing with which the film is liable to come in contact is positively dangerous.

Bulb softening and resultant blistering has been met with in some cases of poorly designed housings. The tubular bulb lamps are of small diameter, as compared with other standard tungsten lamps of corresponding wattages. This permits the condenser and reflector to be set close to the filament, where they intercept a large solid angle of light. The small-diameter bulb results in bulb temperatures, particularly opposite the filament where the heating effect of the spherical reflector is most pronounced, greatly in excess of those found in the case of ordinary commercial units. The bulbs of motion picture lamps are commonly made from a glass which will withstand this higher bulb temperature. In a well-designed housing, with ample ventilation, bulb softening is not encountered.

The tip-up position of operation makes for a lower base temperature, and trouble in this quarter is not ordinarily met with in motion picture and stereopticon lamps.

In the high-current motion picture lamps the lead-in wires were formerly soldered to the base. A poor base contact, due, for example, to faulty socket design, sometimes caused the solder to melt. This difficulty has been eliminated by welding the lead-in wires to the base in these high-current lamps.

Ventilation in a motion picture lamp housing of usual size is essential, and the tendency should be toward more rather than less. The temperature of the bulb is lowered by increased ventilation, as is the temperature of many other parts of the housing.

PART III—VENTILATION VS. NON-VENTILATION

LOCAL RULINGS AFFECTING THE USE OF GAS-FILLED LAMPS.

Soon after the gas-filled lamp was introduced in the early part of the year 1914, criticisms began to be heard because of the greater amount of local heat developed. It will be remembered that the first gas-filled lamps introduced were the 750-watt and 1000-watt, 115-volt sizes and some of the low-voltage high-current lamps. The bulb which felt hot to the touch, the extreme brightness of the filament, and the extraordinary power consumption combined to make the fire hazard appear greater than it really was. In some districts, local inspectors formulated rulings which were so strict that the installation of gas-filled lamps was greatly hindered. While the intent of these rulings was good, the rules in most instances were made without authentic data which afforded a comparison with previous practice.

UNIT	LAMP	DEGREES FAHRENHEIT		
		TEMPERATURE OF WIRE — UNIT NOT VENTILATED	TEMPERATURE OF WIRE — UNIT VENTILATED	LOCATION OF VENTILATING HOLES
	200-WATT DAYLIGHT	164	168	TOP
	500-WATT DAYLIGHT	233	240	TOP AND BOTTOM
	200-WATT GAS-FILLED	140 140	155 148	TOP AND BOTTOM TUBE AND BOTTOM
	200-WATT GAS-FILLED	125	125	TOP
	200-WATT GAS-FILLED	129	130	TUBE

Table No. 10.—Wire operating temperatures.

Almost invariably, rules relating to the installation of gas-filled lamps contained somewhere a reference to ventilation, which was expected to lower the temperature of the exposed surfaces of the unit and at the same time prevent short life of the lamp due to excessive filament temperature.

VENTILATION AND LAMP TEMPERATURES.

There is no doubt that ventilation, however slight, usually cools the lamp bulb and some other parts of the unit to a certain extent, but this is ordinarily accompanied by a corresponding rise in temperature of other parts. One of the most important considerations from the standpoint of the National Electrical Code is the temperature of the wire where it is connected to the lamp socket. A considerable amount of data, some of which are shown in Table 10, indicates that ordinary ventilation does not always cool the wire and socket parts, but actually raises their temperature in many instances.

VENTILATION AND LAMP LIFE.

The erroneous impression that the life of an incandescent lamp is appreciably shortened by surrounding high temperature has also led manufacturers to ventilate in various ways. Theoretically, the filament temperature is increased by high surrounding temperature but this increase is so small relatively at 4300 to 4800° F., the range for regular gas-filled lamps, as to be unnoticeable even on carefully conducted life tests. The melting point of tungsten is given as 6156° F. and from the data given elsewhere it will be noted that there is a considerable margin between the operating temperature and the melting point of tungsten. Tests also show that the high surrounding temperatures which are encountered in special cases affect the lamp performance by causing a blistered bulb, loose base, melted solder, trouble at the stem seal, etc., before they produce any serious effect upon the filament.

VENTILATION AND EQUIPMENT DESIGN.

The application of the term "ventilated" in Rule 77-c. of the 1920 Edition of the National Electrical Code is obviously intended to keep the connecting wires cool.

> "All fixtures should, where possible, be sufficiently ventilated and the wiring should be so disposed as to avoid exposing the wiring to high temperatures."

There have been frequent instances where the interpretation of this rule by local inspectors has made it necessary to drill holes in a unit, thereby not only defeating the purpose of the rule but spoiling the design of the unit as well.

The growing tendency on the part of fixture manufacturers toward non-ventilated units is evidenced by the number of such units that have been placed on the market within the past year. By taking care of heating through radiation rather than ventilation, marked progress has been made, not only toward better control of temperatures, but in the direction of slower dirt accumulation, greater ease of cleaning, better appearance, and greater accessibility as well.

PART IV—SUGGESTIONS ON THE USE OF INCANDESCENT LAMPS IN INTERIORS WHICH PRESENT SPECIAL TEMPERATURE PROBLEMS.

USE OF LAMPS IN DUSTY PLACES.

Extensive research has been undertaken to determine the extent of the hazard resulting from the use of incandescent lamps in atmospheres such as are found in flour mills, grain elevators, etc., where disastrous dust explosions have occurred rather frequently.

At the outset it should be understood that a fire may be started with any incandescent lamp, vacuum or gas-filled, if it is operated for a considerable length of time, when surrounded so that the heat energy must accumulate. When such is the case, the surrounding material will continue to rise in temperature until it reaches that point where the energy is dissipated just as rapidly as it is supplied. If this final temperature is high enough. and if combustible materials are present, a fire may be expected.

Fires or explosions which may be caused by incandescent lamps in dust-laden atmospheres are of two kinds: (1) Fires resulting directly from ignition of dust accumulating on the lamp bulb: (2) Explosions resulting from the accidental breakage of lamps in a dusty atmosphere containing the proper proportions of air and dust to form an explosive mixture. Such an atmosphere is frequently found where such materials as starch, oatmeal, grain, flour, sugar, or chocolate are handled.

FIRES DUE TO DUST ACCUMULATION ON LAMP BULB.

Carbonaceous dusts, such as previously mentioned, when permitted to accumulate on the bulb of a gas-filled lamp will

smoke and produce an odor. However, smoke is not always the result of fire. There is a considerable margin between the smoking and ignition temperatures of the various dusts. There are numerous conditions which determine whether or not this margin is safe, such as the character and the ignition temperature of the dusts and the temperature of the heated body, that is, the lamp bulb on which the dust accumulates. This margin is not the same or nearly the same in all cases, but varies considerably depending upon the composition of the dusts.

From Table 11, it will be seen that the smoking temperature of representative dusts is of practically the same value, and that with only two exceptions, a higher ignition temperature means a larger margin between the smoking and ignition temperatures. It will be noted that disregarding the kind of dust and the ignition temperatures, the smoking temperature varies from 284°

TABLE No. 11—Margin of Temperature Between the Smoking and Ignition Points of Various Dusts

Name of dust	Smoking temp.	Melting temp.	Ignition temp.	Difference between smoking and ignition temperatures
	Deg. F.	Deg. F.	Deg. F.	Deg. F.
Sample No. 2*	288	——	511	223
Sample No. 1†	331	——	513	182
Sample No. 4‡	295	——	532	237
Sample No. 3**	298	——	536	238
Cocoa	313	——	558	245
Graham flour	309	552	883	574
Cornstarch	284	545	891	607
White-wheat flour	315	507	919	604
Cornmeal	311	527	934	623

*No. 2 Approx.
20% Oats
20% Duram
40% Winter wheat
10% Hard winter wheat
10% Miscellaneous

†No. 1 Duram wheat dust

‡No. 4 Approx.
40% Winter wheat
35% Barley
25% Oats

**No. 3 Approx.
60% Oats
35% Winter wheat
5% Rye

to 331° F. These smoking temperatures are about the same as the operating temperatures of the smaller, or lower-wattage gas-filled lamp bulbs, but are 100 to 150 deg. higher than the bulb operating temperatures of vacuum lamps of corresponding

wattages. From this it can be seen why dust smokes readily on gas-filled lamps and not on vacuum lamps.

The temperatures at which the first four dusts, which are unusually chaffy, and cocoa, will ignite are more than 300 Fahrenheit degrees above bulb temperatures of the 75-watt and 100-watt gas-filled lamps and more than 150 Fahrenheit degrees above the bulb temperatures of gas-filled lamps in the higher wattages. Experiments conducted in a compartment where a permanent dust cloud was maintained showed that it is possible, with each of the first four samples listed in the table, to start a fire with the larger gas-filled lamps. All attempts to start a fire with the 75-watt and 100-watt gas-filled or with vacuum lamps up to and including 100 watts were, however, unsuccessful.

The temperatures at which the other dusts will ignite are more than 700 Fahrenheit degrees above the bulb temperatures of vacuum lamps; more than 600 Fahrenheit degrees in the case of 75-watt and 100-watt gas-filled lamps; and more than 500 Fahrenheit degrees in the case of higher-wattage gas-filled lamps. In the experiments conducted on these dusts, no fires were started on any of the lamps. Some of these dusts melted but would not burn.

If any inflammable dust is permitted to collect thickly enough and remain long enough upon the bulb, a fire is almost sure to follow. For this reason it is difficult to set any definite workable limits between bulb temperature and ignition temperature, which may be considered safe in all cases. Vacuum lamps which have bulb temperatures in the vicinity of 150 deg. F. and units having exposed surfaces of the same general temperature range, may be considered safe. The 75-watt gas-filled lamps would hardly be expected to cause a fire when suspended in a freely circulating atmosphere. With the larger wattages and drier dusts, the margin of safety might be so reduced that there would be a possibility of fire.

It appears that the hazard in using gas-filled lamps in general over-head lighting systems in dusty atmospheres is far less than that resulting from careless use of smaller lamps on drop cords by workmen. At times, lamps are allowed to become actually buried

in bins of grain and the like and the fire hazard in such a case is, of course, extremely great with any size of lamp.

EXPLOSIONS DUE TO LAMP BREAKAGE.

The second kind of fire or explosion results from the accidental breakage of lamps in a dusty explosive atmosphere. The possibility of fire from this source is of much greater importance than the one just discussed—that resulting from the collection of dust on an incandescent lamp bulb. Nearly all finely divided dusts having a high carbon content will, if combined with the right proportion of air, explode when brought in contact with an open flame. Tests conducted by the United States Bureau of Mines and the United States Bureau of Agriculture have proved this fact. By their tests, it was also shown that an explosion could be produced by static electricity or by the electric arc. In tests conducted by the lamp manufacturers, it has been shown that in addition to the above, explosions may also occur when the same conditions prevail, if an incandescent lamp is broken in a dust cloud. The same result will be obtained with both the vacuum and the gas-filled lamps.

It is only on rare occasions that incandescent lamps are broken otherwise than by accident or careless usage. The use of an unprotected lamp at the end of a portable cord in a dusty atmosphere is careless in the extreme. However, an explosion may be caused in other ways than by the breaking of the bulb, as, for example, by a short circuit within the socket, a flash from a loose connection, or the like.

As has been stated under the heading "Vapor-Proof Units," the market to-day contains a number of fixtures designed especially for use where explosive gases, or moisture, may be present. Numerous tests on these fixtures have shown that, in general, if a unit has a globe of large diameter with rather straight sides which hinder the accumulation of dust, the unit may be used with gas-filled lamps and still have a globe temperature below the smoking point of the dusts given in the above table.

Whenever there is the possibility of an explosive dust cloud being present, incandescent lamps should be provided with protection against breakage. Vapor-proof units give some degree of protection. A wire guard for the globe of the vapor-proof

fixture will greatly increase its resistance to breakage. The essential point in this connection is that the filament of the lamp should be so protected that there is no possibility of its becoming exposed to the dust-laden atmosphere.

The incandescent lamp is by far the safest illuminant in existance for use in these locations, but its application has been given too little attention up to the present time. Properly installed and properly used, it will be found to fill all requirements.

USE OF LAMPS IN EXPLOSIVE ATMOSPHERES

In certain places, for example where pulverized coal, gasoline, oils, illuminating gases, explosives, etc., are handled, explosive gases or vapors may be present in the air. The incandescent lamp is by far the safest illuminant for such localities. It should, however, be used with protective devices which will eliminate the possibility of the lamp ever being broken so that the hot filament can come in contact with the explosive mixture. Lamps in these surroundings should be handled in a manner similar to that discussed above under the heading "Use of Lamps in Dusty Places."

USE OF LAMPS IN REFRIGERATION ROOMS.

A frequent question in the lighting of refrigeration rooms, such as meat coolers, cold-storage warehouses, etc., is the relative heating effect of vacuum and gas-filled lamps within such interiors. The fact that the vicinity of the gas-filled lamp is comparatively hot gives rise to the erroneous assumption that a gas-filled lamp will heat the interior of such a cold room to a greater extent than will a vacuum lamp of equal wattage. A refrigerator room, from its very nature, is usually constructed in such a manner that its walls are extremely well insulated to prevent the passage of heat and light through them. Therefore, the entire amount of heat and light energy emitted by an incandescent lamp in such a room is eventually absorbed by the walls of the room, and taken up by the cooling system. A vacuum and a gas-filled lamp of equal wattage emit equal total amounts of energy (heat and light combined). Hence, the effect of each of these lamps on the cooling system is exactly the same (see Appendix).

However, if meat, for example, is hung very near a gas-filled lamp in a refrigerator room, it may come under the influence of the local heat of the lamp sufficiently to be thawed out or even spoiled. The degree of thawing depends, of course, upon the proximity of the meat to the lamp bulb. With the lamp a sufficient distance away, no damage to the meat would result.

USE OF LAMPS IN BAKE OVENS.

A case in which excessive temperatures are frequently met with arises in the use of tungsten lamps for lighting the interior of bake ovens. These ovens usually operate with an interior temperature of from 425 to 450 degrees Fahrenheit. Inasmuch as this temperature is too high for the ordinary basing cement and solder, special lamps have been developed for use in such locations. These lamps are given special treatment in such matters as glass, basing cement, solder, exhaust, etc., to enable them to operate satisfactorily in surrounding temperatures of from 425 to 450° F.

APPENDIX.

METHOD OF MEASURING OPERATING TEMPERATURES OF LAMP BULBS, WIRE, AND UNITS.

There are three simple methods available for measurement of lamp, wire, and lighting unit temperatures, as follows:

(1) By thermometer;
(2) By electrical thermo-couple;
(3) By the change of electrical resistance in a wire.

In measuring temperatures upon the surface of a lighted lamp bulb, the procedure is somewhat involved because of the radiant energy emitted by the lamp filament and transmitted through the glass of the bulb. It is, furthermore, difficult to obtain good contact between a thermometer bulb, even a specially curved one, and the glass of the lamp bulb. Then too, the thermometer bulb filled with mercury is an exceedingly good reflector. For these reasons, a reading of lamp bulb temperature taken with a thermometer is lower than those obtained by the other methods mentioned. When an electrical thermo-couple is used, the greater absorption of radiant energy by the comparatively black junction gives readings which are the highest of the three methods.

Measurement by the change of resistance method gives values of temperatures which fall between the readings obtained by thermometer, and those of the thermo-couple. In this experimental work, white silk insulated copper wire was used, a coil being wrapped closely about the lamp bulb. This coil absorbs less radiant energy than the black thermo-couple, and more than the glass and mercury of the thermometer bulb. Hence, it is to be expected that the readings by the change of resistance method will fall between those obtained by the other two methods. Averaging the results of several tests on 100, 200, 300, 400, 500, and 1000 watt lamps, it was found that for the measurement in air one-half inch from the lamb bulb the thermo-couple reading

TABLE NO. 12—MELTING POINTS OF VARIOUS SUBSTANCES.

Substance	Melting Point Deg. F.
Tallow	82
Spermaceti	120
White wax	154
Sulphur	239
Ferrous sulphate	284
Sugar	320
Camphor	348
Silver nitrate	424
Tin	450

is about 11 per cent higher and the thermometer reading about 13 per cent lower than the change of resistance reading. Likewise, for the measurement on the bulb surface, the thermo- couple reading is about 3 per cent higher and the thermometer reading about 7 per cent lower than the change of resistance reading. In the change of resistance method, variations are, of course, introduced by the interception of radiant energy, the obstruction of air currents by the coil on the bulb surface, etc., but these are small and of such little importance from a practical standpoint that they are not considered in this work.

It is possible to obtain a rough check upon the results of the three methods of measurement by placing different substances (Table 12) of which the melting point is known, upon the lamp

bulb at different points. It has been found that the temperatures obtained in this way check closest with the temperatures obtained by the change of resistance method.

In using the change of resistance method, a coil of fine copper wire (No. 33 white silk insulated is well adapted to this

TABLE NO. 13—CHARRING POINTS OF WOOD.

	Deg. F.
Becomes brown in color at	428
Becomes deep brown black at	536
Easily powdered mass at	590
Brown, soft, friable charcoal at	572
Charcoal burns at	716

TABLE No. 14—Temperatures of Combustion of Various Substances

Substance	Begins to smoke Deg. F.	Smokes badly Deg. F.	Ignites Deg. F.
Safety match heads	–	–	392
Cotton thread	230	320	518
Cotton waste	289	338	446
Black insulation braid	365	–	626
Friction tape	212	365	518
Tissue paper	347	–	500
Crepe paper	279	–	536
Excelsior	221	392	644
Black fibre Insulation	473	509	626
Yellow braid rubber-covered wire*	–	464	626
Rubber insulation†			

*Gave off odor at 293 degrees F.; turned black at 518 deg. F.

†Gave off odor at 293 degrees F.; became soft and gummy at 464 deg. F.

purpose) is wound at the point where the temperature measurement is desired. For the average temperature about a lamp bulb at any point, a coil of four turns of this wire, closely wrapped about the bulb and secured thereto by minute bits of friction tape and small drops of sodium silicate solution, has been found

best. More turns result in excessive radiant energy absorption in the coil itself, while fewer turns give insufficient resistance for best results. It has been found that the color of friction tape used for securing the coil to the bulb is of no consequence, provided the size of the strips is small in comparison with the circumference of the bulb at the particular point.

For measuring temperature at the brass and glass junction of the bulb, a coil of from eight to ten turns is wrapped on the glass, just touching the brass. When the temperature at the bulb tip is desired, a flat spiral of some twenty-four turns is wrapped at that point. This point is usually considered only when the lamp is operated tip up. Fig. 6 shows the points usually considered on a gas-filled lamp for measurement of operating temperatures, and the manner in which the coils are placed.

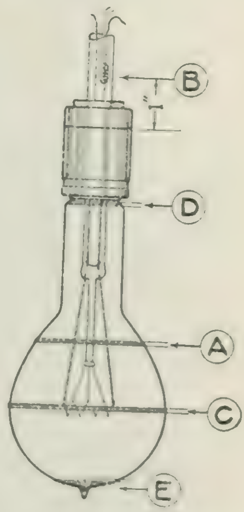


Fig. 6.—Points usually considered in measuring lamp and wire temperatures.

A—Maximum temperature zone.
B—Wire in conduit.
C—Opposite filament.
D—Junction of brass and glass.
E—Tip (If lamp is operated tip up).

Lead-wire temperature is ordinarily measured on the wire at a distance of 1 in. from the end of the wire in the socket. The insulation is stripped from one of the wires for a distance of about 0.25 in., and a coil of about 100 turns of the fine copper wire is wrapped directly about the bare copper conductor; thus the test coil is made to fill the space ordinarily occupied by the insulation. Since there is little radiant energy to be met with at this point, it is possible to have the test coil consist of over-lapping layers.

The ends of the test coils are soldered to heavier leads (No.

18 copper), a separate pair for each test coil. These leads are then run to the terminals of a Wheatstone Bridge. The resistances of the test coils, with their leads, are measured on the Wheatstone Bridge, both when they are cold (room temperature) and when they are hot (lamp in service). It is then necessary to eliminate the resistances of the leads up to the ends of each test coil. To do this, the leads are cut at their junctures with the coil itself. The lead ends are then soldered together, and replaced in a position similar to that which they previously occupied. Then a second run is made, and the lead resistances measured, when they are cold, and when they are hot. Subtracting the cold lead resistance from the cold total resistance gives the cold test-coil resistance. Similarly the hot test-coil resistance is obtained. The following formula is then used to calculate the final coil, or bulb, temperature:

$$T = \left(c + T_{cold}\right)\left\{\frac{R_{hot}}{R_{cold}} - 1\right\} + T_{cold}$$

T = Final coil temperature, degrees Centigrade
T_{cold} = Initial (room) temperature, degrees Centigrade
R_{hot} = Hot test-coil resistance in ohms
R_{cold} = Cold test-coil resistance in ohms
c = Constant depending upon the conductivity of the copper in the test coil

Per cent conductivity	Constant (c)
96	245.1
98	239.6
100	234.5

The room temperature must be kept constant while hot resistances are being measured, and, when practicable, throughout the test. Where the room temperature cannot be kept constant, it is possible by using the above formula to correct the cold resistances, accordingly. Great care should be taken to prevent drafts of air blowing upon, or in the vicinity of, the operating unit. A slight draft blowing upon the test coils when a reading of resistance is being taken causes great variation in the readings, and hence, inaccurate results.

The consistency of this method is evidenced by the fact that successive readings on the same lamp, in general, show a

difference of not more than 0.5 per cent. This is much less than the variation often found between lamps of the same type and wattage. The points at the maximum temperature zone, opposite the filament, and on the lead wire, may be measured with the maximum degree of accuracy. The point at the junction of the brass and glass is more difficult to obtain. A variation of perhaps two per cent is met with at this point. This is probably due to the fact that the brass base is a good conductor of heat and passes on to the test coil the effect of even the slightest draft of air.

The location of the maximum temperature zone on a lamp is determined by spreading a thin strip of sulphur or wax along the bulb from tip to base. Then the lamp is lighted in the desired position, and the point where the layer first melts or discolors is observed.

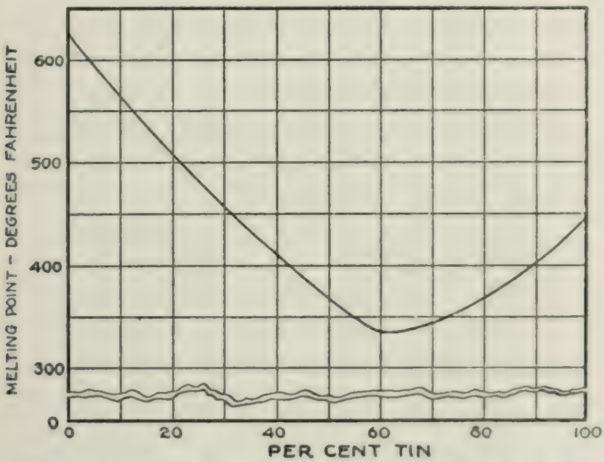


Fig. 7.—Variation of melting point of solder with per cent tin.

In considering operating temperatures, lamps are used at the rated wattage whenever practicable, in order to have a common basis of reference.

EXPONENTIAL EQUATIONS FOR COMPUTING THE VARIATIONS OF OPERATING TEMPERATURE WITH CHANGE OF VOLTAGE.

Where the use of logarithms is convenient, exponential equations may be used for the purpose of computing the varia-

TABLE No. 15—Lamp Wattages and Total Energy Emitted in British Thermal Units per hour.*

Wattage of Lamp	Heat units per hour
40	136.5
50	170.7
75	256.0
100	341.4
200	682.7
500	1706.8
1000	3413.7

*Based on relation, 1 watt = 3.4137 heat units per hour.

EQUIVALENT VALUE OF UNITS.

Degrees Fahr. = 9/5 Degrees Cent. + 32
Degrees Cent. = 5/9 (Degrees Fahr. — 32)
Degrees Kelvin = Degrees Cent. + 273
Degrees Kelvin = 5/9 (Degrees Fahr. — 32) + 273

tion of operating temperature with change of voltage. The equations given below apply only to gas-filled, PS bulb lamps operated in the tip-down position..

Exponent "m" for the zone of maximum temperature

$$\frac{q}{Q} = \left(\frac{v}{V}\right)^m$$

q = degrees Fahrenheit at v volts
Q = degrees Fahrenheit at V (Normal) volts
m = 0.415

Exponent "o" for the point opposite the filament

$$\frac{q}{Q} = \left(\frac{v}{V}\right)^o$$

q = degrees Fahrenheit at v volts
Q = degrees Fahrenheit at V (Normal) volts
o = 0.500

Exponent "x" for the junction of the brass and glass

$$\frac{q}{Q} = \left(\frac{v}{V}\right)^x$$

q = degrees Fahrenheit at v volts
Q = degrees Fahrenheit at V (Normal) volts
x = 0.302

From these exponents, if the temperature at any one voltage is known the temperature at any other voltage may be readily calculated. The values given apply very closely for voltages near and above normal. When voltages very low in per cent of normal are considered, it is necessary to take the value of the exponent from exponential curves which may be obtained from the lamp manufacturers.

DISCUSSION

NORMAN MACBETH: The distribution of heat from an incandescent bulb is ordinarily provided for through ventilation and radiation; admitting cold air to the interior of the accessory, it passes up around the lamp and out through the top, that is, by heating the air passing around the bulb; and by conducting the heat to the outside surface of the accessory.

There is another factor which we have enclosed accessories, that is, the extent of heat transmission through the glass which may partially or entirely surround the incandescent lamp bulb. If you use clear glass, you will get considerable heat transmission. When you use glass where the light transmission is reduced and much of the radiant heat intercepted, the blistering of bulbs and softening of stems will result with housings which in the case of glass affording a reasonable transmission of heat would be satisfactorily ventilated.

E. Y. DAVISON: It is a common belief with the fixture manufacturers of this country that ventilation can only be accomplished by convection. This spring the authors of this paper made tests for us on one of the well known commercial units to ascertain whether the lamp runs cooler with a hole drilled in the bottom than without. It was actually found to run cooler when the hole was not drilled.

We also find a material advantage in decreased dust collection when the hole is absent. Enclosing globes look badly after a few months service due to the accumulated dust deposited on the bottom of the luminaire brought about by the change in the velocity of the air suspending these particles.

I suggest that this word be passed on to the fixture manufacturers. They say they have been taught the wrong method and someone has to teach them the right one now. Each one refuses

to undertake it individually. I believe if our society would present these facts to them as it has been to us to-day they would gladly accept the word and carry it on to the trade.

C. L. Dows: This usual effect of enclosing a lamp with a vapor-proof globe is to increase the lamp bulb temperature somewhat, but the outside temperature of the globe is very much reduced, principally on account of the greater radiating surface. When the most common sizes of gas-filled lamps are surrounded by well-designed vapor-proof globes, the outside temperature of the globes is brought into the range of vacuum lamp bare bulb temperatures.

Filament temperature data on lamps other than those shown here are available.

In passing, I should like to explain why we have expressed our temperatures in Fahrenheit. It was believed that this work would be of more practical value to those designing units and in other commercial ways if expressed in Fahrenheit, although under other conditions we should have used Centigrade. To include both would have been confusing.

The work on grain dust, which is summarized here, has been published before in the Electrical World as the result of an investigation by Messrs. Blackwell, Fox and myself about a year ago, it has been included here to make the work more complete.

ANIMAL LIGHT*

BY E. NEWTON HARVEY**

Mr. Chairman, Members of the Society. Perhaps a better title for the lecture would be "Living Light," because it is not only in the animal kingdom, but in the plant kingdom as well that we find luminous forms.

Fireflies have, of course, been known for centuries to all people, but it is less than fifty years since we have known what the cause of certain other phosphorescences of living things was due to. For instance, the glowing of dead fish or the glowing of meat in refrigerators or the glowing of wood have only been definitely known to be due to living organisms since 1875. In that year it was shown that all these luminescences were due to some organism, plant or animal.

In 1810, there was a paper presented to the Royal Society, by a man named McCartney, setting forth the causes of the light or phosphorescence of the sea. He goes over some of the older theories which had been advanced to account for the phosphorescence of the sea. Some had thought that this light was due to putrefaction because it had been known for a long time that dead matter might become luminous. Others thought that the light of the sea was electric, because it was excited by friction. Others thought that it was phosphoric, that the element phosphorus was present in the sea, which phosphoresced there, as it does on a match. Others thought that the sea imbibed light which it afterwards gave off, much as a phosphorescent mineral, calcium sulphide and others of that group will do.

Finally it was decided that the phosphorescence of the sea was due to animals living in it, and this is the correct explanation. Every phosphorescence of the sea is due to one or another form, usually microscopic, but many visible with the naked eye. I think few people realize how many organisms there are which can produce light. If we look over the different groups of animals, we find that at least forty different orders contain one or more

*A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September [illegible]–29, [illegible].

**Department of Biology, Princeton University.

forms producing light, and at least two groups of plants contain forms producing light. The two plants which produce light are the fungi and the bacteria. All the phosphorescence of wood is due to fungi, and all the phosphorescence of dead meat or fish in refrigerators, and other dead matter is due to the bacteria. These bacteria are very widespread and especially abundant in the sea.

Not only bacteria and fungi but jelly-fish, also minute organisms in the water which are known as dinoflagellates, and many kinds of worms, even earthworms, have been found which produce light; also centipedes, especially a tropical variety, produce light; also a kind of mollusk, something like a clam, that bores in the rocks, can produce light; also many kinds of shrimp and many kinds of cuttlefish or squid; and I have in this bottle here a specimen of a squid which you can look at later, in which the ends of the tentacles contain luminous organs, and as the squid swims through the water, it waves these tentacles around and flashes them much as the firefly. This form is found in Japan and by the Japanese it is called "hotaru ika" or firefly squid.

Finally, we have fish which produce a light of their own, apart from the light which is produced by bacteria growing on the dead fish. The living fish contains organs which in themselves are light-producing, and a great many kinds of fish are known which do this, especially forms living in the deep sea. I have also in that bottle two fish which have very large luminous organs immediately under the eye, and these fish have the power of turning on the light or shutting it off by moving a pigment screen up over the luminous organ. The light of this fish shines continually, but can be turned off or on at will, and if you will examine it, you can see on one side the pigment screen which is drawn up over the eye. The other organ has been left exposed, so you can see what the movement of the screen will do.

Noctiluca is the name of a small form occurring in the sea, and which, perhaps is most responsible for the luminescence or phosphorescence of the sea. Almost everyone knows of this form. It is a small mass of jelly, perhaps a tenth of a millimeter in diameter, so that it is just visible to the naked eye. When this form occurs in enormous numbers, the sea may be red in the

daytime because these animals contain a red pigment, and it will shine like a sea of fire at night whenever it is disturbed. If you examine these small forms with a microscope, you will see that the light appears only in minute spots in the animal. These spots really represent granules of some protein material, and it is the burning of these granules scattered through the substance of the animal which gives the light. They are known as photogenic granules.

Noctiluca is a one-cell animal. When we study the many-celled forms, the larger animals, like the sea-pens or jelly-fish, we find that they may be luminous over the whole of the body so that the whole animal is on fire when it is luminescent, or we may find that the luminous material is only restricted to certain areas, rather large areas. Finally we may find that the luminous material is restricted to very definite small spots, and these small spots constitute the luminous organ proper.

Now, some of these luminous organs are exceedingly interesting from a structural standpoint because they are veritable lanterns. In many ways they resemble the eye because they have a lens, except that the lens in the case of the luminous organ is used for directing the light, whereas in the eye it is used for receiving the light and converging it on to the retina. The more complicated of these luminous organs have not only a lens, they have also a layer of cells which contain a shiny material, and this shiny material makes the layer act as a reflector, so that when the light is produced in the middle of the organ, that which comes back against the reflector is shot forward and out through the lens again, and all the light is directed and concentrated in a beam. Not only does the organ have reflectors, it has also opaque screens, in order to protect the tissues of the animals from any light which may go out the side of the organ, and possibly injure cells around the luminous organ. Because, as you know, light, strong light, at least, is destructive to living tissue, and where we have an organ in the animal producing a light of its own, we have practically a very strong light, and we find in most cases the organs or tissues protected from the light by some kind of a screen.

There may be present pigment screens, color screens, which allow only certain wave-lengths to pass, and so give the light a

certain color, not a great variety of color, it is true, but there have been described luminous cuttlefish from the depths of the ocean, that had at least three colored luminous organs, a blue, a violet and a reddish colored organ.

There is a certain insect from South America, so it is said, which has not only white luminous organs, but also red ones, and these red organs are very conveniently situated at the tail of the insect, and the white organ at the head, so that it is known in South America as the "automobile bug."

Now, there are many sides to the study of animal luminescence, and I am afraid, in the time at my disposal, I will have to select only one or two of these, in which I have been most interested. To the student of evolution, luminous animals offer a great field, but a field in which relatively little is known. Almost everyone is interested in the use of luminous organs to the luminous animals, and unfortunately we can say in only a very few cases what the use of the organ is. Who, for instance, can say what the use of light can be to a luminous bacterium, an organism which is perhaps two thousandths of a millimeter in length, and which has no nervous reactions that a higher form has; or who can say what the use of the light is to a form which occurs living at the surface of the sea, and which also has no nervous system, being a one-cell form, blown hither and thither by the wind?

Apparently, in such cases as this, we must say that the light is merely fortuitous, that it accompanies merely some of the organic changes which go on in the animal. It is a chance phenomenon. On the other hand, it would seem likely that deep sea fishes—and it is chiefly these forms which have the lantern, complicated in structure—must use their light as a searchlight for seeing things in a region where we know very little light penetrates.

Then, on the other hand, a great many forms are known which do not live continually in dark places, and presumably would not use their light for seeing unless they did it at night, and then we know of a great many luminous forms that don't move around at all. Take the sea-pens, for instance. They are almost all luminous and they are simply a colony of animals that live in the mud or sand at the bottom of the sea at a depth of perhaps fifty feet where there is plenty of light. They never move around

from one place to another, yet they are luminous. It has been suggested that they may use that light as a warning. If a predacious fish comes along, the minute the sea-pen is disturbed by the fish, the light is flashed on. That warns the fish and scares him away. But this is a mere conjecture. I think no one has seen it take place.

It has been thought also that animal light may be used as a lure, that certain forms use their lights to attract other forms on which they prey. Whether that is true or not, is also a conjecture, because I don't think anyone has observed that sort of thing in progress.

Finally, it certainly seems to be true that in some forms, the light is used to attract the opposite sex in mating. That is the case in the firefly. Each species of firefly has a light which shines in a certain definite way, and if one is an expert, he can go into the field and point out the different species of fireflies by the interval between flashes, the time of the flashes. The male and female of each species are apparently brought together by signaling in that way. These are just a few instances to show you how animals may use their power of lighting.

This subject has a great deal of interest to the physiologist, particularly in connection with stimulation of the light. Perhaps I should have said previously that we can group all luminous organisms into two great classes. One class produces the light continuously and steadily, all the time, day in and day out, and in this group belong the luminous bacteria and luminous fungi. They are always glowing.

The other great group contains all of the other forms which are luminous and they only produce light if they are stimulated in some way. You may have noticed when you are out on the ocean, you don't see any luminescence, any phosphorescence, unless there is a heavy sea, or the propeller of the boat is churning up the water or unless you are rowing; then the movement of the oars will produce the light. What happens there is simply the agitation of the water, acting as a stimulus to the luminous animals in it, and they turn on their lights.

The more primitive forms can only turn on their lights when stimulated by some external force, but the higher forms, like the

firefly, can turn on their lights without any external stimulation, and this simply means that in the firefly we have nerves which go to the luminous organs and these nerves convey an impulse and that impulse results in a luminescence in the organ. We have there exactly the same thing that we have in any movement of the body. When a muscle moves, it has received an impulse from some nerve going to it, and the greatest physiological problem in connection with luminescence is why that stimulus should set the luminescence going.

We have the same problem there that we have in connection with the nerve muscle stimulation, and if we could solve it in either case, it would apply to the other. If we knew what caused a muscle to contract on stimulation, we could also say why a luminous organ lights on stimulation. However, I am not going to go into that matter to-night.

Thirdly, we can consider luminescence from the point of view of the physical nature of the light, and I judge the members of the Society probably know more about that point of view than any other, because the one thing that we hear concerning a firefly is its efficiency, and the fact that it is a "cold light." That is true for every luminous form which has been investigated.

Later this evening, I am going to show you some luminescence resulting from pouring of water on a powder prepared from luminous animals, and this is accompanied by quite a bright flash of light that lasts for some time. If we study that with a delicate thermometer, there is not any perceptible rise of temperature, at least, any change in temperature is well below one-one-thousandth of a degree, Centigrade, so you see there is no increase of temperature which could possibly be felt by the hand. And, of course, you know that physical studies of this light have shown that the light itself is restricted to a narrow region of the visible spectrum and that there is no infra-red or ultra-violet radiation given off. The spectra of all luminous forms, are merely short continuous spectra, in one or another region of the visible spectrum. Even two species of fireflies may give off a light that is slightly different in spectral content from each other. One firefly will extend a little further into the red region and another may extend a little further into the green. So we get lights slightly different in color, and this can be distinguished by the

naked eye. It has been shown, however, that that difference is a real difference; it is not connected with any eye phenomenon, because these spectra can be photographed and we can see the difference recorded on a photographic plate.

Perhaps the main thing to emphasize in connection with the physical nature of this light is that it is exactly the same as any ordinary light; it can be polarized, reflected and refracted. It is not different in any way, except that the spectrum is relatively shorter. When X-rays were first discovered, some observers immediately turned to luminous animals in the hope of finding some kind of unusual radiation given off by these forms, and the earlier observers were so enthusiastic that they did find a penetrating radiation given off. They found that when they took fireflies and placed them over a photographic plate, which was covered by a piece of cardboard, that some light went through this cardboard, and affected the photographic plate, and there have been several papers published in which the effect of penetrating rays have been claimed.

Later it was proved that the earlier workers had not sufficiently controlled their experiments. The light on the plate was due to something from the cardboard. Especially yellow cardboard was found to give off vapors which would affect the plate and the light from the fireflies did not pass the cardboard at all. We know pretty definitely now that no form of penetrating radiation is given off from any luminous form.

Finally, I am going to take up the chemical nature of the luminescence because that is the subject in which I have been most interested. I find that whenever I mention the fact to people that I am interested in luminescence, they always ask one question, that is, whether the light is phosphorus or not. It is easy to answer in the negative that the light has nothing to do with the element, phosphorus. That is too poisonous to be found in living cells. On the other hand, the light has a very great resemblence to the luminescence of phosphorus. It is apparently a process of a very similar nature which occurs in living cells. In the first place, it is an oxidation and if we remove the oxygen from any luminous animal, the light will disappear entirely and absolutely, and if we again readmit oxygen, the light will come back again.

This is a very interesting experiment, and a very old experiment. In fact, it is one of the first experiments that was ever made on luminous forms, by Robert Boyle in 1667.

Boyle at that time was experimenting with his air pump and among other things he placed a little piece of "shining wood" or phosphorescent wood under the receiver of his air pump. He found that when he exhausted the air, the light disappeared and when he readmitted air, the light returned. Of course, he did not know that it was oxygen in the air which was responsible for the effect, but nevertheless I think we can credit him with the discovery that the luminescence of living things requires the presence of free oxygen.

The second chemical fact is also rather an old one. It was discovered by Spallanzani, an Italian, in 1794, that all luminescence required water, and he showed that he could take any luminescent animal and dry it and the light would disappear, but that if you kept this dried material and at some later time moistened it again, then the light would reappear. So like the experiment with oxygen, we have here another perfectly reversible process, showing that luminous animals require water in order to phosphoresce, and you see what a different process this must be from the phosphorescence of minerals under the influence of radiation of various kinds, in which no water and no oxygen is necessary.

The material that I have here to-night, and that I am going to show you has been prepared simply by taking one of these luminous forms in the sea, a small crustacean, whose name is *Cypridina,* and drying it rapidly. It is better to dry it over calcium chloride in a vacuum, but it can be dried in the air if dried rapidly. If you take those dry animals and grind them in a mortar, you get a powder of this sort. In this powder we have the luminescent material of the animals. When moistened it will give a pretty bright luminescence.

This experiment shows another fact, that luminescence is not a function of living cells in the same sense that the contraction of a muscle or propagation of a nerve impulse is a function of living cells. If you take a muscle and dry it quickly, you won't alter its form or constituents and then if you put it in water again,

although it will look like the original muscle, you can stimulate it as much as you like, and it won't contract. The muscle has lost its contracting power by drying. You can do the same with a nerve. After it has been dried, you can wet it and stimulate it, but it has lost its conducting power. Therefore, we have here a loss of a living function on drying, but we do not get that loss of power of luminescence on drying the luminescent organ of any animal.

Since water and oxygen are necessary, it is likely that some material produced by the cells of the animal is oxidized, and this material is called, to use a general term, the photogen, but to use a more specific term, it is caled luciferin, using the Latin instead of the Greek derivitives.

In fact, not only one material is necessary, but two materials are found to be necessary in order to get light, in addition to water and oxygen. This is the third discovery in connection with the chemistry of luminescence. It was made by a Frenchman, Dubois, in 1887. He found that if he took a luminous extract of an animal, he could separate it into two parts, one containing luciferin, which will oxidize with the production of light, and the other part containing a catalyst or enzyme which accelerated the oxidation of luciferin. The two substances could be separated by a difference in their properties, and that is an experiment which I can show you this evening.

The material which oxidizes with light production, luciferin, is not destroyed on heating, so that if we take some of this powder and extract it with boiling water, we can obtain luciferin in that boiling water extract. If we extract the dry powder with cold water, we, of course, get this luciferin also, but in addition we get the catalyst. In other words, we get the two substances. If we let the cold water extract stand for a while, in time all of the luciferin will be used up, because the catalyst is present. The catalyst will be left behind because it is a catalyst, and very minute quantities of it are sufficient to oxidize very large quantities of luciferin. So in cold water extracts we have the catalyst, which has been called luciferase. The ending a-s-e is given to indicate that it is of enzyme nature, because in biochemistry it is usual to indicate the ending of enzymes with a-s-e.

Therefore, we have luciferin, not destroyed with heat, oxidized in the presence of luciferase, destroyed on heating. So if I prepare those two solutions in two test tubes, so long as the materials are separate, they won't produce any light at all. If I mix the two tubes, we will get the light because we have mixed those two substances in the presence of oxygen and air, and we have all the materials necessary for luminescence.

I could go on and tell you something of the properties of these substances, because I have worked on them a good deal, chemically. We can obtain the substances in solution in water and they can be precipitated by various reagents. They can be worked with like any other substances, although we don't know what the material is. Chemically, luciferin is probably to be placed among the proteins, among the simpler members of the proteins, the peptones or proteoses.

The question as to whether we shall ever be able to reproduce living light becomes the question whether we shall ever be able to synthesize the proteins. Personally I think that will come in time. We can synthesize fats, sugars, and some of the polypeptids, which are very simple proteins, so it becomes a matter of time when it will be possible to synthesize the more complicated proteins of which this luciferin is a member.

One interesting thing in connection with this light is the fact that very minute quantities of luciferin are able to give a light which is easily visible to the eye. I once made a calculation which is exceedingly rough and probably may be twenty-five or fifty per cent off, but which showed that about one part of luciferin in a billion and a half of water will give a light which is visible to the naked eye. The reason such a minute quantity of substance gives a perceptible amount of light is on account of the extreme sensitivity of the human retina, which is capable of seeing an energy change of almost infinitesimally small amount.

Finally we may ask what happens when this substance is oxidized. When luciferin is oxidized, does it go to carbon dioxide like other food stuffs in our body. You know sugar and fat are oxidized to water and carbon dioxide. The question is, can we place this sort of luminescent oxidation in the same category? I think we cannot. Experiment has shown that no

carbon dioxide is produced from the luminescence of an animal, and I think the change that does occur is a very simple change. Although nothing is known about it chemically, we can at least name the material which is oxidized, and for convenience, we can call this oxidation product, oxy-luciferin. That, you see, is a very similar nomenclature to the one which is used for the red pigment of blood. The red pigment of our blood, hemoglobin, when it is shaken with air, becomes oxy-hemoglobin. If you put it under an air pump and exhaust all the air, it returns to reduced hemoglobin or hemoglobin proper. This process is reversible. It will go either one way or the other, depending upon the amount of oxygen present. Of course, in our lungs, all this pigment becomes oxy-hemoglobin. When the blood is carried to the tissues, away from the lungs, this pigment is exposed to a lack of oxygen since the cells take up the oxygen and it becomes reduced hemoglobin.

We can do this same thing with luciferin. We can allow the luciferin to become completely oxidized and then by proper methods we can reduce the oxy-luciferin again and get our luciferin back. The methods for doing that are not quite so simple as the method for reducing oxy-hemoglobin. You can't put it under an air pump and get this reduction, but there are methods of reducing oxy-luciferin, and I think in the luminous animal this occurs. When a firefly flashes, it oxidizes the luciferin to oxy-luciferin. When it is resting, in the dark between the flashes, this oxy-luciferin is reduced back to luciferin, and then the firefly is ready for another flash.

I don't wish to say that all the luciferin in the firefly becomes oxidized in one flash, but part of it does, and in the time between flashes, part is reduced. A reversible process occurs and you will note that this is an extraordinary process from the chemical standpoint. Here is an animal which produces a lamp which burns an "oil," and after that "oil" has been burned, the "oil" is re-formed, and it is ready to be reburned. We have the process simply going back and forth according to the amount of oxygen which is present. Not only from the physical but from the chemical standpoint the firefly is highly economical.

I am sorry that I can't show you reduction of the oxy-luciferin because that takes some time, and the process of reduction is not

as complete as the process of oxidation. You can't ever recover all of the luciferin which has become oxidized, at least I haven't been able to in a test tube. It may be that the living organism does that, but one can recover part of it and in fact enough to show that the process will occur.

So we have, I think, without any doubt the luminous animal's light resulting from the oxidation of a substance which is of a protein nature in the presence of water and a catalyst, and, of course, free oxygen.

Now, in the oxidation of phosphorus, we don't have all these substances necessary, so that phosphorus does not present a perfect parallel to animal luminescence. But we can very easily mimic this animal luminescence with a common substance such as pyrogallic acid. This can be very easily oxidized by some organic catalyst with the production of light. If one takes, for instance, a test tube containing a minute quantity of pyrogallic acid solution, with a little hydrogen peroxide added, and to that test tube adds potato juice, one gets a luminescence. The potato supplies an enzyme that acts as the luciferase does in luminous animals. Pyrogallic acid corresponds to luciferin. The light is weak and for other reasons, I doubt if we will be able to light our houses with potato juice, but it does mimic the process which goes on in living animals, and I think it offers rather conclusive proof that we do actually have this enzymic process going on in living things and necessary for the production of living light.

LUMINESCENCE AS A FACTOR IN ARTIFICIAL LIGHTING*

BY E. L. NICHOLS**

Members of the Illuminating Engineering Society, Ladies and Gentlemen. When I was asked to speak to the society to-night on the work in which I have been chiefly engaged in recent years I selected as my title *Luminescence as a factor in artificial lighting*. It might have been put in the form of a question:

"Is luminescence a factor in artificial lighting or is it ever likely to be?

LUMINESCENCE OF COLD BODIES

The term luminescence is a very broad one. Commonly we think of it as applying to the glowing of bodies at ordinary temperatures.

Here we have two distinct types:

(1) The very wonderful sort of luminescence which Dr. Harvey has just described to us,[1] that is, the form of light given off by marine forms and by certain other animals and plants.

(2) The luminescence, very commonly spoken of as phosphorescence, of certain sulphides and other chemical compounds, which when exposed to light, to the kathode discharge to X-rays or to radium, give off light.

Were it a question of either of these two types of luminescence one would answer, as to whether they were a factor in artificial lighting, by saying "No." As to whether they ever are to be a factor I should say after listening to to-nights paper by Dr. Harvey that probably the chemists of the future and possibly the chemists of our own day, would learn to make luciferine on a large scale, synthetically and that with such material luminescence in artificial lighting might well come about.

These types of luminescence which occur at low temperatures are not the only forms. In the broader sense of the word any

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**Department of Physics, Cornell University, Ithaca, N. Y.

[1] Reference is here made to the paper on Animal Light by E. Newton Harvey.

form of light which is not produced simply as the result of heating; in other words any form which does not obey the ordinary laws of temperature-radiation, is to be classified as luminescence. This greatly broadens the field of inquiry.

Ordinary phosphorescent substances: sulphides, willemite, sidot blende, etc., are very far from being of an order of brightness which would render them useful for lighting purposes. They are pleasant to look at but not intense enough to illuminate their surroundings effectively. We may say as a general rule that anything bright enough to light a room is not good to look *at* and that anything pleasing to look at, like the tubes of glowing material which Dr. Harvey has just shown us, is of too low an order of brightness to be a practical factor in artificial lighting.

Within the last few days I have made measurements on a few of the ordinary phosphorescent substances and I have made out a table from which you can form a definite notion of the essential dimness of such sources of light. To give a concrete idea of the intrinsic brightness I selected as my comparison unit the brightness of a tungsten filament at 2000° C. This represents very fairly the brightness of our incandescent vacuum lamps of to-day. To render the data a little more modern I have expressed them also in lamberts.

The excitation of these substances was by means of an iron spark at a distance of about ten centimeters. The spark was actuated by the step-up transformer designed by W. C. Andrews for this purpose.

Regarded as sources of light all of these materials must be classed as very dim. As may be seen from the values in Table I their intrinsic brightness is of the order of few millionths of that of an ordinary incandescent lamp filament.

Unless someone discovers a means of making luminescent bodies that are vastly brighter than the best now known, luminescence may be excluded altogether as a factor in artificial lighting.

LUMINESCENCE OF INCANDESCENT BODIES

Luminescence of the types we have been considering, and these are the only forms generally recognized as such, ceases below

TABLE I.

THE INTRINSIC BRIGHTNESS OF FLUORESCENCE.

Fluorescent substance	Brightness*	Brightness in lamberts
Synthetic Willemite (L)	2.23×10^{-5}	1.405×10^{-2}
Synthetic Willemite (A)	1.99×10^{-5}	1.254×10^{-2}
Natural Willemite (F. F.)	0.84×10^{-5}	0.531×10^{-2}
Sidot Blende (R)	1.74×10^{-5}	1.096×10^{-2}
Sidot Blende (V)	1.04×10^{-5}	0.655×10^{-2}
Sidot Blende (M)	0.485×10^{-5}	0.308×10^{-2}
Calcium Sulphide (Balmain)	0.20×10^{-5}	0.126×10^{-2}
Canary Glass	1.16×10^{-5}	0.731×10^{-2}
Calcite (Langban)	0.0210×10^{-5}	0.0132×10^{-2}
Cadmium Phosphate (A)	0.0029×10^{-5}	0.0018×10^{-2}
Uranyl Potassium Sulphate	5.60×10^{-5}	3.52×10^{-2}
Uranyl Ammonium Sulphate	3.66×10^{-5}	2.30×10^{-2}
Uranyl Rubidium Chloride	1.29×10^{-5}	0.811×10^{-2}
Uranyl Potassium Nitrate	1.20×10^{-5}	0.753×10^{-2}
Uranyl Nitrate	1.05×10^{-5}	0.661×10^{-2}
Uranyl Caesium Nitrate	0.910×10^{-5}	0.571×10^{-2}
Uranyl Acetate	0.857×10^{-5}	0.537×10^{-2}
Uranyl Potassium Fluoride	0.746×10^{-5}	0.469×10^{-2}
Uranyl Caesium Acetate	0.725×10^{-5}	0.456×10^{-2}
Uranyl Lead Acetate	0.594×10^{-5}	0.375×10^{-2}

*The unit of brightness in this column is that of a tungsten filament at 2000° C.

the red heat. There is however powerful luminescence of incandescent matter and this type has been for many years a more or less important factor in artificial lighting. The light from Nernst glowers, mantle burners and luminous flames in which carbon is not the glowing material is in part due to luminescence. The same is likewise true of flaming arcs, vacuum tubes and such sources as the lime-light.

Many years ago E. Wiedemann[2] put forth the suggestion that colored flames, such as the sodium flame are luminescent and Ebert[3] established this claim upon an experimental basis by demonstrating that the intensity of such flames is essentially independent of their temperature.

Ebert found that the temperature of flames could be increased by the introduction of free oxygen or diminished by the use of carbon dioxide, through a range of several hundred degrees

[2] E. Wiedeman. *Annalen der Physik*, XXXVII, p. 177 (1889).
[3] Ebert: *Jahrbuch fur Photographie und Reproductionstechnik*, [illegible]

without appreciably changing the brightness of their spectra: from which he concluded that the radiation was not due primarily to temperature. The views of Wiedemann and of Ebert on the nature of colored flames have since been corroborated by Bancroft and Weiser,[4] Trautz[5] and other physical chemists and I have very recently found confirmation of the luminescence of such flames from the structure of their spectra; which like the typical spectra of fluorescent bodies at ordinary temperatures are made up of series of equidistant bands.

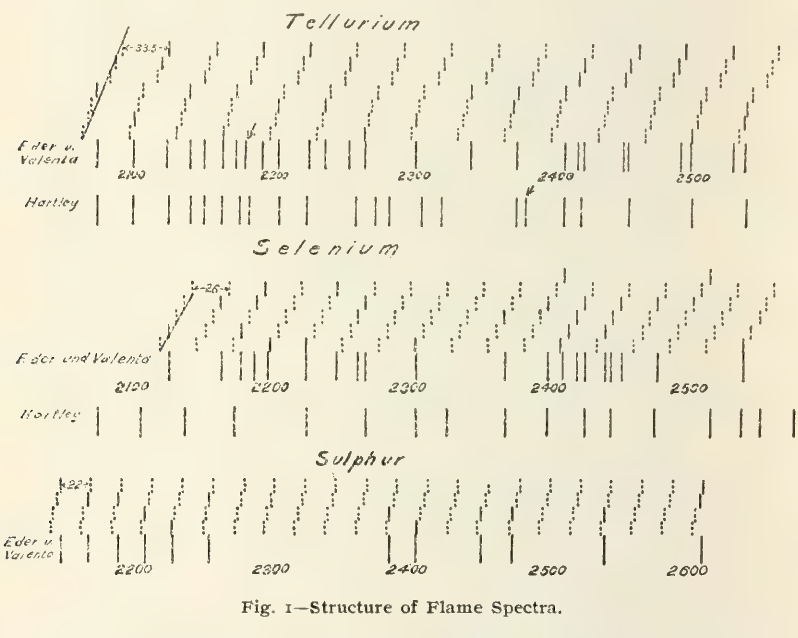


Fig. 1—Structure of Flame Spectra.

In Fig. 1 are given charts of the flame spectra of tellurium, selenium and sulphur which exhibit this characteristic structure. At the bottom of each diagram are the locations on a frequency scale of the bands found by Eder and Valenta[6] and by Hartley.[7] Above it is shown that these bands are members of series having a constant frequency interval of 33.5 for tellurium, 26.0 for selenium and 22.0 for sulphur.

[4] Bancroft and Weiser, *Journal of Physical Chemistry*, XVIII p. 281 (1914) and in subsequent members.

[5] Trautz, *Zeitchrift der Physikalischen Chemie*, XVII, p. 675 (1905).

[6] Eder and Valenta, *Atlas Typischen Spectren*, p. 7.

[7] Hartley, *Phil. Trans.* (1894) p. 161.

That such a structure is found in all flame spectra and that, since it is only known in luminescence we are justified in including this class of flames among luminescent bodies, will be developed in a forthcoming paper. By virtue of their spectra we are led, in the same way, to include flaming arcs and the radiation from vacuum tubes among luminescent sources.

That certain incandescent solids have superimposed upon their temperature, true luminescence of considerable intensity has been brought out definitely and quantitatively, only very recently. This type of luminescence was not altogether unknown but it has been almost completely overlooked because it is accompanied by and is blended with the usual temperature radiation. Where recognized at all it has simply been classified as *selective radiation*. This is not a sufficient designation because a body

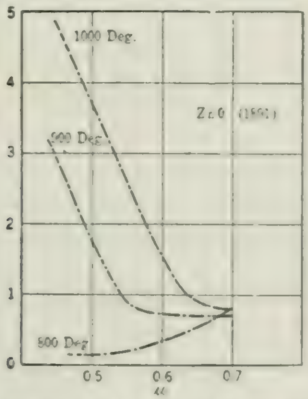


Fig. 2—Distribution of Intensity in the Spectrum of Luminescent Zinc Oxide.

that radiates by virtue of its temperature alone can never surpass, in any part of the spectrum, the radiation from an ideal black body at the same temperature. That certain oxides, when heated to incandescence do however radiate many times as intensely as a black body—for a given temperature and wave-length—has been definitely known for thirty years.[6] Fig. 2

[6] **Nichols and Snow, *Phil. Mag.* (5), XXXIII, p. 19 (1892).**

is from measurements by the present writer and B. W. Snow made in 1891. It gives the brightness of the radiation from zinc oxide at 800° C., 900° C. and 1000° C. referred to that of the same wave lengths from a black body at those temperatures. The black body radiation is represented by the horizontal line at ordinate unity. The curves indicate the relative brightness of the light from ZnO at the temperature in question.

It will be seen that at 800° the oxide is a poorer radiator than the black body throughout the spectrum, as befits a whitish, transparent substance. The radiating power at that temperature diminishes markedly towards the violet.

At 900° a band is developed in the blue-violet and the entire spectrum beyond 0.56 μ is *brighter than that of a black body.* This luminescence band, the crest of which doubtless lies in the violet or ultra violet, is much stronger at 1000° but at somewhat higher temperatures, not indicated on the diagram, it disappears again. Clearly, if we were to use a surface of zinc oxide at 1000° for artificial lighting we should obtain a light more intense than that from a black body and of a bluish tone.

LUMINESCENCE BY FLAME EXCITATION

If instead of heating zinc oxide electrically on a strip of platimum as was done in the experiments just described, a hydrogen flame is used, luminescence of another type will be observed. In the outer zone of the flame which separates the inner region where reduction takes place from that where oxidation occurs by access to the surrounding air. The phenomena thus produced which, are common to many substances, have recently been described.[9]

Measurements of the brightness of a coating of zinc oxide thus heated, observations being made through a red screen (equivalent wave length 0.65 μ) gave the results indicated in Fig. 3. Curve E is for intensities within the active zone, curve U for intensities outside that zone but at the same temperature. These are to be compared with the corresponding intensities of a black body, curve B.B.

[9] Nichols and Wilber, *Physical Review* (2), XVII, p. 453 (1921).

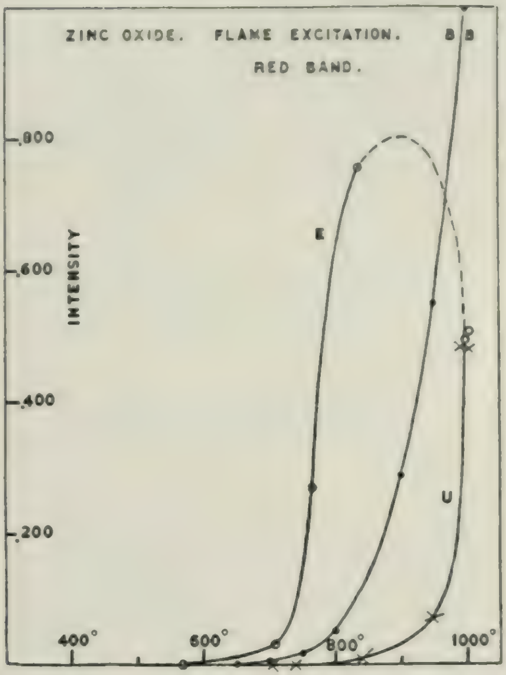


Fig. 3—Intensity of Luminescent Zinc Oxide under Flame Excitation.

It will be noted that up to 800° C. the excited region is much brighter than a black body at the same temperature while the unexcited region, although of the same temperature, is much dimmer. At about 1000° C. the outburst in luminescence is over, the zinc oxide is of the same brightness within and outside of the active zone and each is about half as bright as the black body at that temperature. At the height of the effect, which occurs at about 800°, the luminescent oxide is eleven times as bright as the ideal black body and at the same temperature it

is 115 times as bright as the non-luminescent oxide (See Table II and Fig. 4.) Thus by exciting this oxide to luminescence; *i. e.*, by providing conditions for alternate reductions and oxidations at the edge of the hydrogen flame, we increase its radiation more than one hundred fold.

TABLE II.

RATIO OF BRIGHTNESS $\frac{\text{ZnO (luminescent)}}{\text{ZnO (non-luminescent)}}$

Temp.	Ratio	Temp.	Ratio
565° C.	1.00	815°	115.0
650	12.5	850°	58.0
700°	28.0	900°	22.5
750°	43.5	950°	1.00

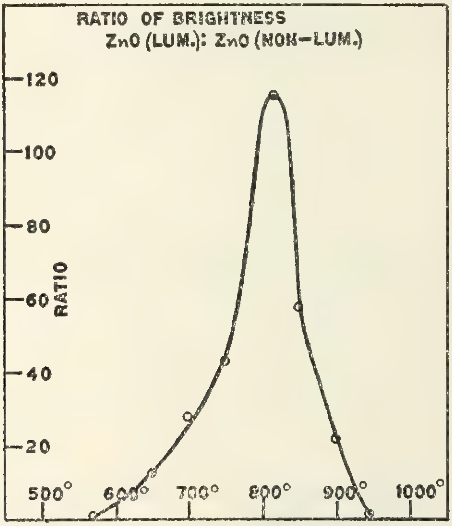


Fig. 4—Brightness of Luminscent and Non-luminscent Zinc Oxide compared.

This effect is accompanied by other changes in the properties of the substance. The emission for instance, as may be seen from Table III and Fig. 5, passes through, a minimum at the temperature (800°) which corresponds to the maximum of the luminescence. Within the temperature range where the out-

burst occurs there are also disturbances in the value of the electrical resistance of the oxide as has been recently pointed out in a paper before the American Physical Society.[10]

TABLE III.

EMISSIVITY OF ZINC OXIDE ABOVE THE RED HEAT

Temp.	Emissivity	Temp.	Emissivity
700° C	0.295	850°	0.096
750° C	0.206	900°	0.123
800° C	0.104	1000°	0.500

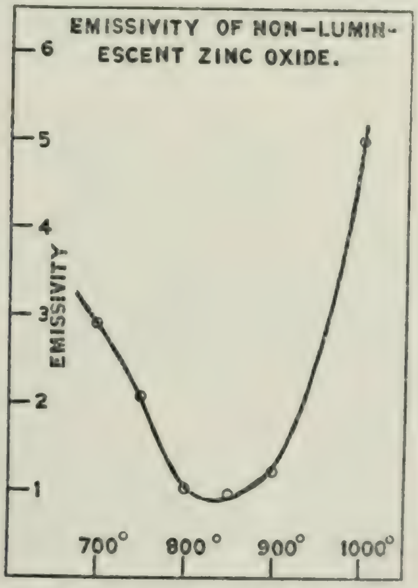


Fig. 5 Changes in the Emissivity of Zinc Oxide.

THE BLUE GLOW

Another form of luminescence obtained between the red heat and 1000° C. has been called the *blue glow*[11] because when brought to the temperatures of low incandescence the substances exhibiting it appear *blue* instead of red.

[10] Nichols, *Physical Review* (2), XVII p. 4[illegible] (1921).

[11] Nichols, A paper with this title to be presented at the Rochester meeting of the Optical Society of America, Oct. 26, 1921.

This effect has been observed in various oxides such as CaO, MgO, BeO, ZnO, SiO_2, Al_2O_3 and certain of the rare earths; also in the mineral fluorite. It is favorably seen when the substances in question are heated by means of the H-O flame being, like luminescence by flame reaction, dependent on free oxygen; but the presence of a flame is not necessary to the production of the glow. The blue glow, like very many other forms of luminescence, is intimately related to and dependent upon some process of oxidation. It is markedly subject to fatigue and is affected by previous heat treatment. Like luminescence by flame excitation it is a phenomenon associated with conditions of instability and of transition from one state of equilibrium to another, and it is often followed at still higher temperatures by other and more complicated manifestations of luminescence.

When the light from bodies exhibiting the blue glow is measured we find that the blue of the spectrum which contains the luminescent light is vastly brighter than the corresponding region in the spectrum of the black body and that the ratio is greater the lower the temperature, running to hundreds or even thousands at the lowest point at which measurements are possible.

The red end of the spectrum which consists wholly of temperature radiation is on the other hand exceedingly weak at the lowest temperatures and approaching that of the black body as the temperature rises.

A typical care is that of aluminum oxide the brightness of the radiation from which for 0.45 μ and 0.65 μ in terms of the corresponding intensities of a black body is given in Table IV.

TABLE IV.

THE BLUE GLOW OF ALUMINUM OXIDE

	Ratio: I(Oxide)÷I(B.B.)			Ratio: I(Oxide)I÷(B.B.)	
Temp.	0 65 μ	0.45 μ	Temp.	0.65 μ	0.45 μ
665° C.	0.000676	1900	1263° C.	0.288	2.50
735°	0.00128	276	1328°	0.357	2.37
837°	0.00536	42.6	1394°	0.438	2.34
960°	0.0214	10.7	1462°	0.448	2.13
1037°	0.0408	5.22	1476°	0.479	2.19
1097°	0.0798	3.18	1484°	0.547	2.16
1145°	0.119	2.92	1503°		2.15
1190°	0.168	2.83			

The curve in Fig. 6 shows the extraordinary fall of this ratio for 0.45 μ from nearly 200° at 665° very low values at 1000°.

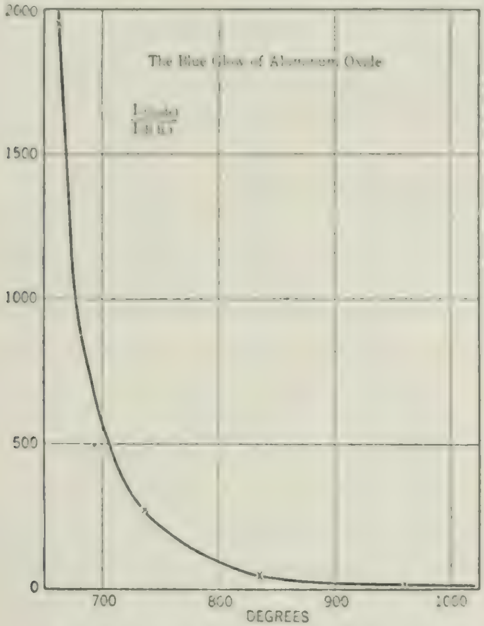


Fig. 6—The Blue Glow of Alumnium Oxide.

THE LUMINESCENCE OF SOLIDS ABOVE 1000° C.

This is likewise a phenomen of instability, frequently if not always indicative of some transformation or rearrangement of the molecular structure. It is to be observed in several of the oxides already mentioned, notably in CaO, SiO_2 and BeO, in other minerals and in several of the rare earths. It is often, but by no means always associated with the *blue glow*.

A striking example, where the two effects are combined is that of certain varieties of fluorspar which when heated first glow blue and afterwards as a temperature between 1200° and 1400° is approached burst into strong luminescence of almost the whole visible spectrum.

The phenomenon is graphically shown in Fig. 7 in which the readings from Table V are plotted in two different ways. In Fig. 7 (A) the ratios of the brightness of two wave lengths, 0.45 μ

TABLE V.

The Luminescence From Incandescent Fluorspar

	Brightness of Fluorspar			Ratio = I(fl.)/I(b. b.)		
Temp.	0.65 μ	0.50 μ	0.45 μ	0.65 μ	0.50 μ	0.45 μ
735°	.00000124	.000276	.0263	.000995	0.224	21.3
837°	.00000239	.00596	.0661	.000975	0.243	2.70
960°	.0700	0.459	2.46	0.167	1.000	5.35
1037°	0.990	9.23	26.5	0.507	4.73	13.6
1097°	7.80	53.1	102.4	1.31	8.96	17.2
1145°	116.0	394.0	316.0	8.77	29.9	23.9
1190°	836.0	1024.0	468.0	31.4	38.5	17.6
1228°	955.0	1334.0	653.0	20.9	29.2	14.3
1263°	1035.0	1545.0	938.0	13.5	19.9	12.2
1294°	1067.0	1679.0	1334.0	9.23	14.5	11.5
1328°	1480.0	1820.0	1799.0	8.30	10.2	10.1
1362°	1622.0	1758.0	1915.0	6.10	6.61	7.20
1394°	1800.0	2019.0	2270.0	4.63	5.19	5.82
1462°	1334.0	1928.0	1000.0	1.60	2.33	1.21
1500°						

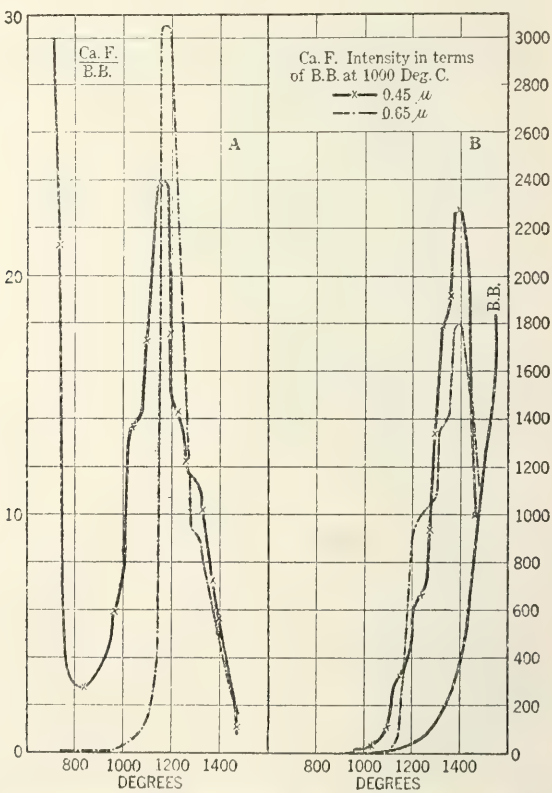


Fig. 7—Outburst of Luminescence from Incandescent Fluorite.

and 0.65 μ, to that of the corresponding regions in the spectrum of a black body at the same temperatare are plotted. In Fig. 7 (B) all ordinates are intensities in terms of that of a black body at 1000° C. In the latter diagram we have a picture of the luminescent radiation super-imposed upon the temperature radiation and of an incandescent body which is actually *brighter at 1400° than when it is further heated to 1500°.*

Like the blue glow these cases of luminescence above 1000° are subject to fatigue and are profoundly dependent upon the previous heat treatment of the material. The detailed account of these effects and the methods by which they are being studied will be given in a paper now in preparation.

The luminescence of incandescent bodies below 1000° has been mentioned in this paper, not because it is likely to be importance in artificial lighting in the present stage of its development but because it obviously affords possibilities in the future. Luminescence above 1000°, however, has already had a certain part in illumination. Some if not all of the oxides which enter into the composition of Nernst filaments, of gas mantels and of the refactory bodies used to enchance the light of certain are lamps are capable of luminescence, as are the lime[12] and zirconium oxide of the old fashoned Drummond light and Lindemann light.

It is true that the radiation from these various sources shows such insignificant departures from the ordinary temperature radiation pertaining to the state of incandescence to which they are brought as to warrant the generalization that luminescence is at best a very minor factor. This is probably due to the fact that luminescence of the forms considered here ceases at temperatures (1300° to 1500°) lower than those to which the bodies used in lighting have been heated. Coblentz, some years ago, described the gradual passing of the very highly selective radiation as observed in the Nernst glower into the ordinary type of temperature radiation at commercial working conditions.

[12] Nichols and Crehore *Physical Review*, (1) II, p. 161 (1894).

LUMINESCENCE OF NASCENT ZINC OXIDE

There is however powerful luminescence of a metallic oxide which is continually employed in a very special form of artificial lighting.

I refer to the luminescence produced in an incandescent solid in the burning of metallic magnesium, the flame of which owes its great actinic power to the extraordinary outburst of blue and violet radiation from the newly formed magnesium oxide. The temperature at which this effect occurs was studied thirty years ago under the writer's direction by F. J. Rogers[13] who also explored the visible spectrum. The part which the luminescence of solids may play in illumination is perhaps better illustrated by the results of this investigation than by any other data as yet available. Interpreted into modern terms, which was not possible at the time when the experiments were made, we find that:

(1.) The color temperature *i. e.*, that to which the radiation, as indicated by the distribution of intensities in the spectrum, corresponds is about 5000° C. The curve is nearly identical with that of an overcast sky.

(2.) The actual temperature, as estimated by the use of a platimum-rhodium thermo-junction is about 100° above that of the average temperature within a Bunsen flame *i. e.*, not over 2000° C. This means that only about 2 per cent of the radiation from the magnesium oxide in such a flame is temperature-radiation and that more than 98 per cent is due to luminescence.

(3.) Of the 6,010 calories liberated by the burning of a gram of magnesium it was found that no less than 4.630 calories or 75 per cent were in the form of radiant energy of which nearly 14 per cent lay in the visible spectrum. The total efficiency or *light energy* is therefore about 10 per cent of the heat of combustion; a value unapproached I believe among the known transformations of energy used in the production of light.

Luminescence is then chiefly responsible for the extraordinary performance of this oxide. Were the comparatively abundant metal available at a price which permitted its use as a light-making fuel, the magnesium light would have a field in practical

[13] Rogers, *American Journal of Science*, XLIII p, 301 (1892).

illumination. Unfortunately the oxide will repeat its luminescent glow, only in greatly diminished intensity upon reheating to the temperature of the flame. Whether its pristine brilliancy can be restored by any process short of reduction to the metallic form and re-oxidation by combustion is not as yet known. Herein lies a difficult but possibly remunerative field for investigation.

A LOW-VOLTAGE, SELF-STARTING, NEON-TUNGSTEN ARC-INCANDESCENT LAMP.*

BY D. MCFARLAN MOORE.**

A quarter of a century ago, a lamp was conceived of that paralleled the then supreme 3.6-watt per candle carbon incandescent lamp, but the light of which was to radiate from a gas, in contra-distinction from a heated solid.

Such a lamp in a complete form has not yet been produced, but many new varieties of gaseous conduction lamps have been evolved, each one of which possesses one or more of the dozen or so most essential features, but usually in combination with some undesirable feature that in some instances was new. For example, high efficiency was obtained by resorting to vacuum tubes, several hundreds of feet long, such a lighting system or lamp being far from equivalent to a simple incandescent lamp bulb. Other interesting lamps of this character were objectionable in requiring either high voltage or high frequency or auxiliary apparatus, consisting of condensers, reactances, resistances, electrode heating circuits, etc., for either starting or normal operation. Other lamps had an objectional color, short life, poor efficiency or low intensity.

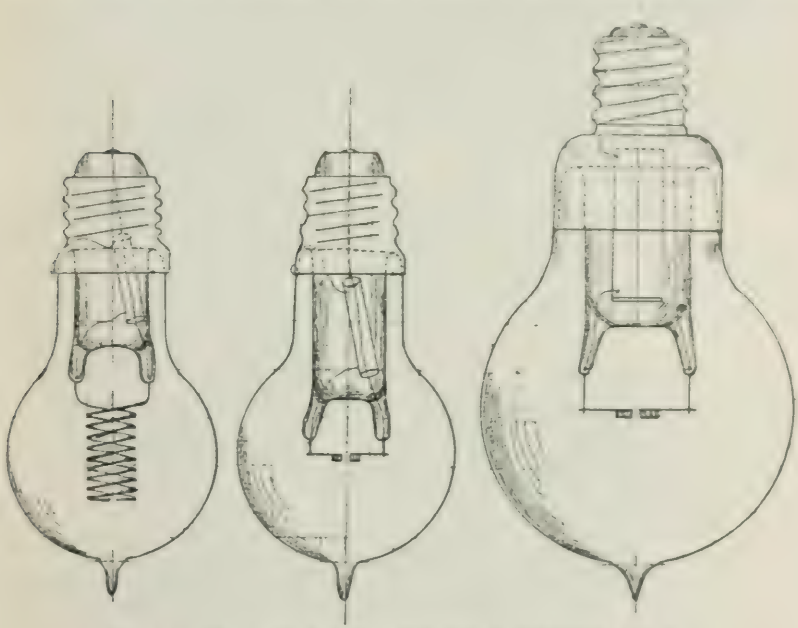
For many years it seemed impossible to obtain any gaseous conduction phenomena with less than 220 volts. However, perhaps the lamp described by the author in a paper presented to the A. I. E. E. on March 6th. 1920, covered a lamp most nearly approaching the goal sought for. In two main particulars, the lamp described was not perfectly satisfactory, the candle-power per lamp being too low for most uses, and the watts per lumen much too high. At the present time all theory seems to indicate that to increase materially the luminous efficiency of light sources in general, one must resort to gaseous radiation by means of which

* A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., Sdptember 26-29, 1921.

** Edison Lamp Works of General Electric Co., Harrison, N. J.

it may be possible to reduce to about one tenth the energy now required.

Figure 1 shows one of the many forms of what may be called a plain corona or cold-radiator lamp, 2¼ in. in diameter. It is the first commercial electric lamp whose radiating wires which correspond to the filament of an ordinary incandescent lamp, are



Figs. 1, 2 and 3.—Types of Neon-Tungsten Incandescent Lamps.

"cold" (that is, they operate below red heat). Even though it is a gaseous-conduction lamp, (that is, there is not a continuous metallic circuit within the lamp) it operates on 110-volt circuits and has a power consumption as low as 0.25 watt from the supply system.

The light consists of a velvety pinkish glow or corona enveloping the paralleled wire helices. These helices are 0.75 in. in diameter and 1 in. long and are made of aluminum or iron, etc.

A series resistance of several hundred ohms is placed in the base. The bulb contains about 30 mms. of neon gas. With less gas pressure and higher voltage, this lamp is ideal for signalling purposes, because it is entirely extinguished instantly,

upon the opening of its supply circuit; no time is required for the radiators to cool, as proven by stroboscopic tests.

Its mechanical design is almost ideal as regards cheap construction but its specific consumption is high (about 15 watts per spherical candle-power) and it is difficult to obtain sufficient candle-power from a single bulb for most uses. When this is attempted by raising the voltage and lowering the value of the series resistance, destructive arcing discharges are liable to occur and the helices become red hot. This type of lamp lends itself for operation on either alternating or direct-current circuits; in the latter instance its appearance is good, although only one helix (the negative) glows.

If for the large helices there are substituted small ones of refractory material, like tungsten, as indicated in Fig. 2, a different type of lamp is evolved, which may be designated as an intense corona—because some of its light is due to radiations from hot solids. A power consumption of two or three watts from the supply system will cause a bombardment that results in an incandescence of properly designed electrodes or radiators, thus producing light at a specific consumption fai better (about 3.0 watts per spherical candle-power) than when the radiators remained cold.

Upon closing the controlling switch of such a lamp, which has a series resistance of 624 ohms in its base, there first appears surrounding the electrodes a close fitting electric glow or corona discharge of light, having the characteristic reddish color of neon and the current flowing is about 0.02 amperes with a power consumption of 5.5 watts, but the current steadily increases so that in a few seconds, it reaches stability, at 0.125 amp. (the consumption being 26.2 watts) and the dim reddish corona evolves into a horizontal cylinder of intense source of white light of about 7.1 spherical candles apparently about ⅜ in. in diameter and ½ in. long. That is, a bright and comparatively efficient gaseous conductor light has been produced on low voltage circuits, without the use of any starting auxiliary apparatus. This result has been accomplished by so constructing the electrodes that a greater current would flow.

In the specific instance of the lamp shown in Fig 2, the

electrodes consist of twenty turns of 0.0025 in. tungsten wire, wound on a mandrel 0.050 in. in diameter. The gap between the electrodes is $^1/_{16}$ in. The helix form lends itself particularly well for using all of the energy of the corona glow. Heated helical and many other forms of radiators have been tried.

When higher amperes are desired proper provision must be made for using several electrodes or increasing the diameter of the electrode wire. Fig. 3 shows a lamp in which the electrodes consist of twelve turns of 0.010 in. tungsten wire on a 0.050 in. mandrel. In this instance the bulb contains 65 mm. of neon gas. A series resistance of 303 ohms is used on a 220-volt 60-cycle circuit. Upon closing the switch, the red corona glow appears over all of the electrodes at 0.06 amp., but quickly changed to a ball of white light about ⅝ in. in diameter at 0.32 amp. The output was 10.5 spherical candles and the power consumption was 85 watts, of which 31 watts was used in the resistance. Therefore, the 54 watts of the lamp at 128 volts on the lamp corresponded to 5.1 watts per spherical candle.

When highly efficient reactance is used to replace the ohmic resistance, the actual power consumption is correspondingly reduced. The evaporation of the tungsten is regulated by the current density and the gas pressure. Such lamps can be made in sizes from very low to very high wattages. When operated on direct current, only one electrode becomes incandescent but the self-starting characteristics are the same.

If the intense corona lamp, last above described, has its series resistance changed from 303 ohms to 40.0 ohms, the sudden change in phenomena is so marked that there is created a different class of lamp which can be designated as an "arc," or as the first low-voltage, self-starting, neon-tungsten-arc-incandescent lamp.

When the current is applied, the same phenoma as before occurs, first the faint corona glow (cold electrodes) followed rapidly by the intense corona (hot electrodes) at 0.32 amp., but the current continues to rise to 4.45 amp., and the heads of the helical electrodes become much more highly heated and their tails cool to redness, while at the same time a very intense white arc appears in the gap between the electrodes. The voltage on the

lamp terminals also falls from 128 volts to 42 volts. The output increases from 10.5 to 178 spherical candles and the specific consumption becomes 1.08 watts per spherical candle.

It is seen that very efficient and simple arc-incandescent lamps can be made for outputs from very low candle-powers to very high candle-powers.

The use of this simple progressive starting method is applicable to a large number of gaseous conductor devices, including rectifiers of all kinds. Lamps based on this principle can be used for many purposes, from general illumination to projection lantern service.

THE PARIS MEETING OF THE INTERNATIONAL COMMISSION ON ILLUMINATION*

BY EDWARD P. HYDE**

The recent meeting of the International Commission on Illumination, in Paris, marked in a way the real beginning of the Commission. In 1913 the Commission was organized at Berlin out of the International Photometric Commission. This latter Commission had been created by the Gas Congress of 1900 at Paris and had had a dozen years of useful service in promoting international agreement, particularly in the photometry of Gas Lamps.

The newer Commission was organized as a more representative body of all lighting interests, and on a somewhat broader basis. It was intended that the Commission should convene every three years and the second meeting was scheduled to be held in Paris in 1916. On account of the war it was impossible to hold this meeting. Moreover, the formation of national committees was retarded and the complete organization of the Commission was not consummated. It, therefore, became necessary when the war was over to proceed with the organization on a slightly different basis and the meeting in Paris, held July 4th to 8th, was the outcome.

It is most encouraging under the circumstances that so little time was taken up, at this meeting, with organization matters and that Commission concerned itself so largely with technical subjects.

The following countries were represented; France, Great Britain, Italy, United States, Switzerland, Belgium and Spain. The national committees of Great Britain, France, Italy and the United States submitted papers or technical reports as the basis for discussion and international action. The presentation of papers on various live subjects of illumination was most gratifying, for it inaugurated a policy of broader activity and usefulness than could ever be achieved if the work of the Commission were

*A Report presented before the Annual Convention of the Illuminating Engineering Society, Sept. [illegible] 1921.

**Director, Research Laboratories, National Lamp Works of the General Electric Co., Cleveland, Ohio.

restricted to questions of international standardization. In all, approximately, fifteen papers and technical reports were presented.

One of the most important subjects before the Commission was that of Nomenclature and Standards.[1] The decisions of the international body on this subject were restricted to the definitions of the three fundamental quantities "Luminous Flux," "Illumination" and "Luminous Intensity," together with the corresponding units. This would seem to be but a meagre accomplishment, but, in view of the difficulties encountered among the various nations with respect to their viewpoints and their practices, the accomplishment is significant. The foundation of international agreement on Nomenclature and Standards has been laid, and through the activities of a committee which was appointed with our illustrious friend and member, Monsieur Blondel as chairman, it is expected that a much fuller report will be prepared for adoption at the next meeting of the Commission three years hence.

Among other subjects considered are to be mentioned "Lighting Legislation for Factories and Schools" and "Automobile Headlights" and the difficult subject of "Heterochromatic Photometry" in its many aspects. No international agreement was reached on any of these subjects but a number of committees were appointed to prepare reports for consideration at the next meeting of the Commission. A Committee on Factory and School Lighting" will serve under the chairmanship of Mr. L. B. Marks. A Committee on "Automobile Headlights" will be presided over by Dr. C. H. Sharp, the chairman of our committee on the same subject. A Committee on "Heterochromatic Photometry" will work under the chairmanship of Prof. Charles Fabry, the well known French Physicist.

You will all be gratified to know that it was decided to hold the next meeting of the Commission in 1924 in the United States if conditions of ocean travel make this plan feasible at that time.

It is neither the time nor the place to dwell upon the social side of the meeting although it was an important and pleasant feature. I wish to express my personal appreciation of the delightful and profitable entertainment accorded the delegates and also to

[1]See Report of I. E. S. Committee on Nomenclature and Standards, 1921 TRANSACTIONS, Vol. XVI, No. 7, pp. 246.

mention the admirable way in which the organization of the Commission was carried out under the guidance of President Vautier. It is with much pleasure that I report that Monsieur Vautier was elected the first honorary President of the Commission, to the organization and work of which, as well as to that of its predecessor the International Photometric Commission, he has given so unsparingly and so efficiently of his time and effort. The new officers elected are as follows:—President, Dr. E. P. Hyde; Honorary President, Th. Vautier; Vice-Presidents, M. F. Rowland, M. G. Semenza, K. Edgecumbe; Honorary Treasurer, C. C. Paterson; Honorary Secretary, C. C. Paterson; Assistant Secretary, J. W. T. Walsh.

THE INDUCTION OF PRESIDENT-ELECT CRAMPTON

PRESIDENT HARRIES: The time has about arrived for me to pass the President's gavel to my successor. I have but one regret to express now and that is that a physical disability made it impracticable and perhaps to some extent impossible for me to do some of the things I would have liked to have done during my term of office.

However, as we all manage somehow or other, again I take refuge in and comfort from the Mass—all of us do those things which we ought not to have done, and leave undone those things which we should have done. I am not without comfort. I want to thank those who relieved me of much of the physical burden of presiding at the sessions. I want to thank some of those who preceded me, perhaps most especially Mr. Doane, my immediate predecessor, and associates generally; the Council which is really a Council and looks after the interests of the Society perhaps even better than the Society as a whole could do it; the Secretary who did as usual. I have no doubt he was as helpful to my predecessors as he has been to me. They may not as openly admitted it, but no doubt it is true. I thank the officers—highly efficient and altogether worthy of it.

To the Society as a whole I am grateful for the honor bestowed upon me, but I have still larger measure of gratitude for the very kindly consideration, not as a whole, although it could be so measured if one so desired, but individually. There is nothing which lives so eternally as sentiment. All other and material things are subject to change, but the fine affection which is my possession, given to me by you is, after all, the most precious thing and in return for that, you have not only my gratitude, (wholly inadequate term) but my own strong personal affection in reciprocating that which you have bestowed upon me.

The Society does mean to me very much technically although we hardly need to discuss that. It has a very great and rapidly growing value, but it is the personal side of it, it is the individual something that to me at this time seems to be preeminent.

If I can ever serve you (and I don't mean now in high place; I am not seeking office. I am thankful I never did hold an office

that I sought. I never sought an office. That is not in a spirit of foolish independence, but I never did, and it is in the kindliness of my fellowmen that I owe very much that I have that is really worth while), I hope you will call on me. I thank you very sincerely for all you have done, for all you have been and all you are to me, and hope that we shall continue to be to each other just the very best that human nature would permit us to be.

If Past Presidents Doane and Stickney will take physical possession of Dr. Crampton and escort him to the platform, I shall be under renewed obligation.

....Dr. Crampton was escorted to the front by Messrs. Doane and Stickney..... (Applause)

PRESIDENT HARRIES: Gentlemen, formally I want to present to you a fine soldier, a fine scientist, and one who will be an uncommonly fine President. (Applause)

DR. GEO. S. CRAMPTON: It is going to be very difficult for me to adequately express my appreciation of the high compliment which you have conferred upon me, or rather upon the ophthalmologists of the country, by electing one of their number as your President.

It will be extremely hard for one who is not an illuminating engineer, although deeply interested in the Society for the past seven or eight years, to fill this office, and naturally I look to you all for assistance. I have been assured that I will have the cooperation of the members of the Society in my endeavor to make this a year unique in its history. I would not feel justified in accepting this office were it not for this assurance and the feeling of strength with which it inspires me. So I am going to ask you to come forward and do more than you have ever done before. I want every man—I am sure I am not asking too much—every member of the Society, to work as he has never worked before. I have ambitions for the Society, ambitions that I am afraid you will think are very high, but we might as well hitch our chariot to a star. We may have a little drop at the end of the year, however, I am going to propose a plan that I have suggested to a few of the members of the Society. I am almost afraid you will laugh at it, but I am going to propose that during the coming year we will double the membership of this Society. This achievement seems impossible

at first glance, unless you stop to realize that at the present time there is a splendid opportunity for development of this Society in the middle West beyond the Mississippi River, in so far as sections are concerned, and the surface has barely been scratched. There are states in which we haven't a single member. There are large cities in which we haven't even so much as a chapter.

I am glad to say that we now have a chapter in Canada. I hope we will have more. I hope we will go into Canada with our propaganda of good lighting and aid her illuminating engineers to put their work across until such time as they may choose to have a society of their own. I hope we will be able through schools and various methods that will be proposed later, to organize our work in those cities in which there is no real organization at present, for instances, such cities as St. Paul, Minneapolis, St. Louis, New Orleans, and out through the cities of the west, wonderful cities. Those people all have eyes; those people are all handling lighting and I feel that we are very selfish and self-satisfied to be content with a comparatively small organization and deprive those other communities of the benefit of just such information as you have received during this wonderful convention. You may print bulletins and issue data, you may write letters and you may try to reach these communities in that way, but you will never reach them in the way this convention was reached this morning by Mr. Goodwin through his direct talk. I noticed when he was talking to the Society this morning that every man's eyes were riveted on him. You could almost see the dotted lines. He was indeed a magnet, and I realized what a privilege it must be to have the power to impart information in that manner and the opportunity to reach the very men who can and do appreciate the knowledge gained. I thought as he was delivering his paper that it was the sort of paper which, with all due compliments to the author, many of us wouldn't stop in our busy lives to read, but to hear it from him, right straight from the shoulder, it was wonderful, and it is through word of mouth that you get your real results. We are so busy that we only can read one-tenth perhaps of what we would like to read, but when you get a chance to sit down leisurely and have the desired information given to you in this way, it inspires you.

We have a busy year before us, and you will hear further of the activities of this Society, I mean to say the organized attempt to increase the membership, I feel we have a propaganda that is worthy of a big membership and worthy of a bigger attendance at the conventions, and I hope that each man here will do what he can towards a larger attendance next year, and that we will have a larger attendance of the ladies because they help to make a successful convention. They are the queens of the home, and we can spread a good deal of our propaganda through the ladies.

I accept this high honor that you have paid me solely as a very humble representative which you have chosen from the ophthalmologists of the country, and I thank you most sincerely for the confidence you have placed in me.

TRANSACTIONS
OF THE
Illuminating Engineering Society
PART II -- PAPERS

VOL. XVI NOVEMBER 20, 1921 No. 8

REPORT OF THE COMMITTEE ON LIGHTING LEGISLATION*

The Code of Lighting for factories, mills and other work places was issued by the Illuminating Engineering Society in 1915. In 1918 the code was slightly revised.

Since the first publication of the code, lighting codes based upon the Illuminating Engineering Society's code have been put into effect in the following states: Pennsylvania, New Jersey, New York, Wisconsin, Oregon, California and Ohio. The adoption of the code is now under consideration in several other states.

Developments in the science of lighting and experience gained by the operation of the code in the several states have indicated the need of further revision especially in relation to the glare rule and the intensity rule. There has been an insistent demand by the states to make the requirements of the code more specific in order that the factory inspector may have less difficulty in applying the rules in practise.

In the revised code which is presented to-day, the Committee has endeavored to incorporate all of the practical suggestions that have been placed before it since the present revision was begun in February of last year. A departure has been made in arranging the text for ready reference by dividing the subject-matter into three parts: Part I containing the rules, Part II containing suggestions and general information with notes relating to each rule and Part III containing a statement of the advantages of good lighting. The suggested mandatory requirements for safe lighting are all set forth in Part I. It is thought that the inclusion in Part II, of a table of intensities for detailed industrial operations and processes and of tables classify-

*A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

ing light sources from the standpoint of glare, will go far toward meeting the demand for more specific information on these subjects.

To carry out the work of revision three sub-committees of the Committee on Lighting Legislation were appointed as follows:

RULES	APPENDIX
W. T. Blackwell	C. O. Bond*
M. G. Lloyd	C. E. Clewell (Chr.)
L. B. Marks, (Chr.)	Ward Harrison (Vice-Chr.)
W. J. Serrill	S. G. Hibben
G. H. Stickney	W. F. Little

EMERGENCY LIGHTING

Louis Bell
J. W. Cowles (Advisory)
R. H. Maurer
G. B. Regar (Advisory)
R. E. Simpson (Chr.)

The sub-committee on rules was charged with the preparation of Part I. The sub-committee on appendix was charged with the preparation of the introduction and of Parts II and III. Much of the work including the preparation of the tables relating to glare, was carried out under the immediate direction of the Vice-Chairman of this sub-committee. In view of the special requirements of exit and emergency lighting, the formulation of the rule relating to this subject was placed in the hands of a separate sub-committee. The work of the sub-committees was submitted to the committee as a whole and approved in its present form.

In June, 1920, the Illuminating Engineering Society accepted the invitation of the American Engineering Standards Committee to act as sponsor for the industrial lighting code. Since that date the revision of the code has been carried out under the rules of procedure of the American Engineering Standards Committee. Pursuant to these rules a Sectional Committee was appointed consisting of representatives of the following societies and organizations: Illuminating Engineering Society, American Institute of Electrical Engineers, American Society of Mechanical Engineers, National Electric Light Association, National Safety Council, International Association of Industrial Accident Boards and Commissions, American Gas Association, Association of Edison Illuminating Companies, United States Bureau of Standards, Na-

*Deceased.

tional Workmen's Compensation Service Bureau, United States Public Health Service (Department of Industrial Hygiene), United States Department of Labor.

In addition to the sessions of the Committee on Lighting Legislation and of its sub-committees named above, parallel sessions devoted to the revision of the code were held by the Sectional Committee. It is expected that formal approval by the American Engineering Standards Committee will follow in due course.

Respectfully submitted,
Committee on Lighting Legislation.

COMMITTEE ON LIGHTING LEGISLATION

Louis Bell	W. F. Little (*Sec'y.*)
W. T. Blackwell	M. G. Lloyd
C. O. Bond*	M. Luckiesh
F. C. Caldwell	A. S. McAllister
C. E. Clewell	L. B. Marks (*Chr.*)
C. W. Cutler	R. H. Maurer
Ward Harrison	G. B. Nichols
S. G. Hibben	W. J. Serrill
J. A. Hoeveler	R. E. Simpson
A. R. Holden	G. H. Stickney
O. L. Johnson	L. A. Tanzer
Clarence L. Law	F. A. Vaughn

*Deceased.

CODE OF LIGHTING—FACTORIES, MILLS AND OTHER WORK PLACES

INTRODUCTION

The accompanying Code of Lighting for factories, mills and other work places has been prepared and issued by the Illuminating Engineering Society in order to make available authoritative information for legislative bodies, factory boards, public service commissions and others who are interested in enactments, rules and regulations for better lighting. The Code is intended also as a guide for factory owners and operators in their efforts to improve lighting conditions in their factories.

Part I contains Rules arranged in convenient form for legal enactment or governmental regulations.

Part II contains a discussion of the rules of Part I; that is, the legal requirements which must be met where a Code is in force; and also suggestions and general information as to desirable practice in factory lighting.

Part III takes up the advantages of proper and adequate illumination, both natural and artificial, and discusses such lighting particularly from the standpoint of economics.

Since the first edition of this Code was issued, a number of the states of the Union, recognizing the beneficial effects of adequate illumination on the health and safety of the employees, have adopted factory lighting codes. As a rule, these codes stipulate the minimum illumination permissible for different classes of industrial operations. They also indicate the desirable, as distinguished from the minimum illumination values, and the kinds of lighting equipment which will avoid glare and give a good distribution of light.

The preface to the Wisconsin Industrial Lighting Code explains as follows why the state is concerned in the regulation of Factory Lighting:

"Insufficient and improperly applied illumination is a prolific cause of industrial accidents.. In the past few years numerous investigators, studying the cause of accidents, have found that the accident rate in plants

with poor lighting is higher than similar plants which are well illuminated. Factories which have installed improved lighting, have experienced reductions in their accidents which are very gratifying.

"Of even greater importance, poor lighting impairs vision. Because diminution of eyesight from this cause is gradual, it may take the individual years to become aware of it. This makes it all the more important to guard against the insidious effects of dim illumination; of glaring light sources shining in the eyes; of flickering light; of sharp shadows; of glare reflected from polished parts of the work. To conserve the eyesight of the working class is a distinct economic gain to the state, but regardless of that, humanitarian considerations demand it.

"Finally, inadequate illumination decreases the production of the industries of the state and to that extent, the wealth of its people. Factory managers, who have installed improved illumination, are unanimous in the conviction that better lighting increases production and decreases spoilage."

Mr. R. E. Simpson of the Travelers Insurance Company is authority for the statement that during the year 1919 there were more than 2,000,000 industrial accidents causing loss of time; of this number 25,000 were fatal. The following extract from an article in the *Travelers Standard* by Mr. Simpson gives some interesting data on the relation between lighting and safety:

"There is some foundation for assuming that 18 per cent of our industrial accidents are due to the defects in lighting installations. On that basis the services of 108,000 men for one year are lost annually because the illumination provided is not adequate for the safety of the workmen. That this condition could exist year after year is all the more reprehensible, because of the fact that the remedy is so easily applied, and has beneficial results in many ways other than the safety involved. Accidents caused by carelessness, inattention or ignorance can be eliminated only by a long continued, painstaking, educational campaign, often involving a change in long established habits. Elimination of accidents, due to inadequate or improper lighting is simply a matter of purchasing the proper equipment, and installing it under competent directions. In fact, it seems proper to include illumination in the list of mechanical safeguards, for the reason that the lamps and reflectors provide a guard; illumination points out the hazards just as effectively as a railing points out the danger of, and provides protection against, the hazard of a revolving fly wheel."

PART I.

RULES.

Note: Attention is called to the fact that the requirements given in the Rules are minimum specifications and are not to be interpreted as sufficient to insure good lighting, see PART II,—Suggestions and General Information.

General Requirement. Traversed spaces, during the time of use, and work in process, shall be supplied with light in accordance with the following rules:

Rule I. Illumination Required. The illumination maintained shall be not less than given in the following table:

TABLE I.

		Minimum foot-candles On the space or at the work
(a)	Roadways; yard thoroughfares, ...	0.02
(b)	Storage spaces; aisles and passageways in workrooms, excepting exits and passages leading thereto,..........	0.25
(c)	*Where Discrimination of Detail Is Not Essential*:........ Spaces, such as:—Hallways, stairways; exits, and passages leading thereto; toilet rooms; elevator cars and landings. Work, such as:—Handling material of a coarse nature; grinding clay products; rough sorting; coal and ash handling; foundry charging.	0.5
(d)	*Where Slight Discrimination of Detail Is Essential*:...... Spaces, such as:—Stairways, passageways and other locations where there are exposed moving machines, hot pipes, or live electrical parts. Work, such as:—Rough machining, rough assembling; rough bench work; rough forging; grain milling.	1
(e)	*Where Moderate Discrimination of Detail Is Essential*:.. Work, such as:—Machining; assembly work; bench work; fine core making in foundries; cigarette rolling.	2
(f)	*Where Close Discrimination of Detail Is Essential*:........ Work, such as:—Fine lathe work; pattern making; tool making; weaving light colored silk or woolen textiles; office work; accounting; typewriting.	3
(g)	*Where Discrimination of Minute Detail Is Essential*.... Work, such as:—Watchmaking; engraving; drafting; sewing dark colored material.	5

Rule 2. Avoidance of Glare: Diffusion and Distribution of Light.

Lighting whether natural or artificial shall be such as to avoid glare, objectionable shadows and extreme contrasts, and to provide a good distribution of light; in artificial lighting systems, lamps shall be so installed in regard to height, location, spacing, and reflectors, shades or other suitable accessories, as to accomplish these objects.

Bare light sources, such as exposed lamp filaments or gas mantles, located within the ordinary field of the worker's vision, are presumptive evidence of glare.

For a specification of definite requirements under this rule, reference should be had to Tables III, IV, V and VI in Part II.

Rule 3. Exit and Emergency Lighting. The lighting to be provided under Rule 1 in all stairways and exits of factories and in the passageways appurtenant thereto shall be supplied so as not to be subject to failure because of the failure of the room or work space lighting from internal causes, and preferably from an independent connection extending back to the main service entrance for the building. In case of unusual danger which may exist on account of type of building, nature of the work, crowded conditions or lack of suitable exit space, an independent service shall be ensured by connecting to a separate source of supply without or within the building.

PART II.

SUGGESTIONS AND GENERAL INFORMATION

Notes on Rule 1—Illumination Required.

The illumination values given in Table I are minimum requirements dictated from the viewpoint of safety. Table II given below is intended to indicate the order of illumination values that are considered desirable for different classes of work. Letters in parenthesis following foot-candle values, refer to the corresponding sub-divisions of Table I. Persons of advanced years and those with defective eyes require more light than those having perfect vision. The foot-candles in good lighting practice are as a rule several times those specified as minimum requirements. A range of foot-candle values is given in Table II for each group of operations; in modern practice it will usually be found desirable to select values in or even beyond the upper portion of the range.

TABLE II.

APPROXIMATE FOOT-CANDLES IN GOOD LIGHTING PRACTICE ON THE SPACE OR AT THE WORK

1/20 TO 1/4 FOOT-CANDLES (a)

Roadways and yard thoroughfares.

1 TO 2 FOOT-CANDLES (b)

Storage Spaces: aisles and passageways in work rooms, excepting exits and passages leading thereto.

2 TO 5 FOOT-CANDLES (c) and (d)

Auditoriums and *Assembly Rooms.*

Assembling: rough.

Boilers, Engine Rooms and *Power Houses*: boilers, coal and ash handlings, storage-battery rooms; auxiliary equipment, oil switches and transformers.

Chemical Works: hand furnaces, boiling tanks, stationary driers, stationary or gravity crystallizing; mechanical furnaces; generators and stills, mechanical driers, evaporators, filtration, mechanical crystallizing, bleaching.

Clay Products: grinding; filter presses, kiln rooms, molding, pressing, cleaning and trimming.

Elevator, Cars and *Landings*: (freight and passenger).

Forge Shops and *Welding*: rough forging.

Foundries: charging floor, tumbling, cleaning, pouring and shaking out.

Glass Works: mix and furnace rooms, casting.

Hallways: stairways, exits and passages leading thereto.

Leather Manufacturing: vats, cleaning, tanning and stretching.

Locker Rooms.

Meat Packing: slaughtering.

Machine Shops: rough bench and machine work and rough assembling.

Milling and Grain Foods: cleaning, grinding or rolling.

Packing: rough.

Paint Shops: dripping, spraying, firing.

Paper Manufacturing: beaters, machine grinding.

Plating.

Receiving and Shipping.

Soap Manufacturing: kettle houses, cutting, soap chip and powder.

Steel and Iron Mills: charging and casting floors, muck and heavy rolling, shearing, rough by gage, pickling and cleaning, soaking pits and reheating furnaces.

Store Rooms and Stock Rooms: rough.

Textile Mills: (Cotton) opening and lapping, carding, drawing-frame, roving, dyeing; (Woolen) carding, picking, washing and combing.

Toilet and Wash Rooms.

Woodworking: rough sawing and rough bench work.

5 TO 10 FOOT-CANDLES (e) and (f)

Assembling: medium fine.

Chemical Works: tanks for cooking, extractors, percolators, nitrators, electrolytic cells.

Clay Products: enameling; coloring and glazing.

Cloth Products: light goods.

Electric Manufacturing: storage battery, molding of grids, coil and armature winding, mica working, insulating processes.

Engine Rooms and Power Houses: switchboards, engines, generators, blowers, compressors.

Forge Shops and Welding: fine forging and welding.

Foundries: fine molding and core making.

Glass Works: grinding, glass blowing machines, cutting, pressing, knitting, sorting, stitching, trimming and inspecting.

Hat Manufacturing: dyeing, stiffening, braiding, cleaning and refining, forming, sizing, pouncing, flanging, finishing and ironing; sewing: light goods.

Ice Making: engine and compressor rooms.

Inspecting: rough, medium.

Leather Manufacturing: cutting, fleshing and stuffing; finishing and scarfing.

Leather Working: pressing and winding; grading, matching, cutting scarfing; sewing: light goods.

Machine Shops: medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing.

Meat Packing: cleaning, cutting. cooking, grinding, canning, and packing.

Milling and Grain Foods: baking, roasting.

Office: private, general.

Packing: medium, fine.

Paint Shops: rubbing, ordinary hand painting and finishing; fine hand painting and finishing.

Paper Manufacturing: calendaring, finishing cutting and trimming.

Polishing and Burnishing.

Printing Industries: matrixing and casting, miscellaneous machines, presses; proofreading, lithographing, electrotyping.

Rubber Manufacturing and Products: calendars, compounding mills, fabric preparation, stock cutting, tubing machines, solid-tire operations, mechanical goods building, vulcanizing; bead building, pneumatic tire building and finishing, inner-tube operation, mechanical goods trimming, treading.

School: class room, study room, library.

Sheet Metal Works: miscellaneous machines, bench work; punches, presses, shears, stamps, welders, spinning.

Shoe Manufacturing: hand turning, miscellaneous bench and machine work; inspecting and sorting raw material, cutting, lasting and welding: light goods.

Soap Manufacturing: stamping, wrapping and packing, filling and packing powder.

Steel and Iron Mills: bar sheet and wire products; automatic machines, rod light and cold rolling, wire drawing, shearing, fine by line.

Store Rooms and Stock Rooms: medium; fine.

Structural Steel Fabrication.

Textile Mills: (Cotton) spooling, spinning, drawing in, warping, weaving, quilling, inspecting, knitting, slashing. (Silk) winding, throwing, dyeing, quilling, warping, weaving and finishing. (Woolen) twisting, and dyeing; drawing in, warping; weaving; knitting machines: light goods.

Wood Working: sizing, planing, standing, machine and bench work, gluing, veneering, cooperage, finishing.

10 TO 20 FOOT-CANDLES AND ABOVE

Assembling: extra fine.

Cloth Products: dark goods.

Glass Works: glass cutting (cut glass), inspecting fine.

Glove Manufacturing: dark goods: sorting, stitching, trimming, and inspecting.

Hat Manufacturing: sewing: dark goods.

Inspecting: fine.

Jewelry and Watch Manufacturing: engraving, stone setting, fine repairing.

Leather Working: grading, matching, cutting, scarfing, sewing: dark goods.

Machine Shops: fine bench and machine work, fine automatic machines, fine grinding, fine buffing and polishing.

Office: drafting room.

Paint Shops: extra fine hand painting and finishing (automobile bodies, piano cases, etc.)

Printing Industries: linotype, monotype, typesetting, imposing stone, engraving.

Shoe Manufacturing: inspecting and sorting raw material, cutting, stitching: dark goods.

Textile Mills: woolens; weaving dark goods.

In Tables I and II the illumination requirements are specified in foot-candles. The term "foot-candle" may be explained by saying that it represents the illumination on a surface one foot distant from a standard candle; two foot-candles would represent the illumination supplied by two candles at the same distance, etc. In this illustration it is assumed, of course, that in each case the surface is perpendicular to the direction of the rays of light falling upon it.

At first sight it might appear from Tables I and II that there is a sharp line of demarcation between those operations for which one foot-candle is specified and those which require two foot-candles, etc. In reality no such well defined classification exists and in applying the Tables the inspector will find that in certain cases, because of the degree of fineness of the work carried on in a particular plant, one grade higher or one grade lower than that which first suggests itself may be a more reasonable requirement.

Again, it should not be overlooked that there are occasional operations which need to be performed practically without light,

such as photographic and photometric processes in dark rooms. Again, there are some operations which are best observed by their own light, as in certain parts of the process of working with glass. In all cases in which work must be performed under very low illumination, special precaution should be taken to safeguard the workers from accident.

In applying the illumination requirements as given in Tables I and II the foot-candles specified should not be construed as referring only to a horizontal plane; the illumination should be measured on whatever plane the work or operation is carried on, whether it is on a horizontal, vertical or intermediate plane. With most artificial lighting systems the foot-candles measured on a vertical plane are about one-half the illumination in the same location measured on a horizontal plane. Attention is also called to the fact that the values in Table I are minimum values; that is, they apply to measurements of the lighting system in ordinary operation, not simply when the lamps and reflectors are new and clean.

Natural Lighting—The foot-candle values given apply to natural as well as to artificial lighting. In practice it will be found that the natural illumination on clear days is frequently many times these figures; in fact, an illumination of a hundred foot-candles can be found in almost any shop if measurements are taken near the window, and very often mechanics find it worth while to avail themselves of this illumination by walking over to the window whenever extremely accurate measurements are to be made. In this connection it is of interest to note that the range of illumination under which the eye can function with some degree of success is extremely wide, varying from a few hundredths of a foot-candle in the moonlight up to as much as ten thousand foot-candles out in the sunlight on a clear day However, wide extremes in illumination are ordinarily not conducive to best vision.

Most factory owners are particularly interested in making the best possible use of their daylight facilities, so as to render useful and valuable all parts of the floor space; and also, to shorten the periods when artificial lighting is needed. The saw-tooth sky-windows of modern factory construction (Fig. 1), permit of

an adequate and nearly uniform daylight illumination of the entire floor area, and are desirable when practicable. When rooms are illuminated through side windows, it is often difficult, or impossible, satisfactorily to light all parts of the floor space, or to furnish adequate illumination to some of the workers without furnishing too much to others, or without subjecting the latter to objectionable glare. In some cases the use of prismatic glass which redirects the rays of light so as to admit more daylight into the room, especially into the parts of the room remote from the windows, is worth while. As a rule it is better to confine the prismatic glass to the upper sash of a window, as its use in the lower sash is likely to cause objectionable glare; moreover it cuts off all view of out of doors.

Windows should be equipped with adjustable devices so that the illumination may be accomodated to changing exterior conditions. Translucent window shades of light tones constitute the most important of these devices. Window shades or other daylight adjusting devices should not be left to the mercy of those workers who may be nearest the windows, but should be controlled by the room foreman. He should readjust the window equipment for the varying daylight conditions and he should, also, decide when the use of artificial light to make up for a deficiency in daylight in any location, is permissible.

Because of the time required for the adaptation of the eye to its surroundings special danger is present when one steps from outdoor sunlight into a dimly lighted storage space; for example, a passageway connecting two well-lighted areas must be well illuminated. Again, where the eye has been afforded the advantages of a high level of illumination throughout the day and artificial light is turned on to reinforce the failing natural light, a higher total illumination is ordinarily needed than at night under artificial lighting alone.

Maintenance of Illumination—The proper and adequate maintenance of equipment for both natural and artificial lighting is essential. Systems which are adequate when first installed will soon deteriorate unless properly maintained. The factory owner should establish a regular, definite system of maintenance so as to insure that sky windows, side windows, lamps

and accessories are at all times kept clean, in proper adjustment and in good repair. Means should be provided for easy access to all lighting units by the employee in charge of their maintenance. Walls and ceilings should be repainted, preferably in light tones, at regular intervals, particularly where, as in indirect systems of lighting, a large part of the illumination comes from the ceiling. It should be kept in mind that the illumination requirements given in the tables apply to the lighting equipment under adverse operating conditions, not simply new and clean as when first installed.

Figs. 2 and 3 show the very considerable loss in illumination which results from the collection of dirt on lamps and lighting fixtures. To insure that a given level of illumination will be maintained even where conditions are favorable, it is necessary to design the system to give initially at least 25 per cent more light than the required minimum. In locations where the dirt will collect rapidly and where adequate maintenance is not provided the initial value should be at least 50 per cent above the minimum requirement, and it is evident from a study of the charts that even this allowance may prove insufficient.

Especially in connection with the maintenance of lighting systems attention is called to the desirability of having available in the factory some instrument with which the foot-candles of illumination received at any point, can actually be measured. There are a number of such instruments on the market, some of which, in the hands of experienced men, are capable of a high degree of accuracy. One instrument, the foot-candle meter (Fig. 4), is not designed for precise measurement, but nevertheless, has a considerable field of usefulness because its determinations are easily made and are accurate enough for many practical purposes. The foot-candle meter is small, light in weight, and does not require technical training for its operation; foot-candle illumination is read directly from the scale without computation or adjustment. In one large establishment where the superintendent uses a foot-candle meter systematically as a check on his maintenance department, readings of illumination are taken at regular intervals at fixed stations throughout the plant. These readings are recorded in such a way that the successive readings are readily comparable.

PLATE 37L

Fig. 1.—Saw tooth roof construction, with glass facing the north sky, usually results in well diffused daylight illumination.

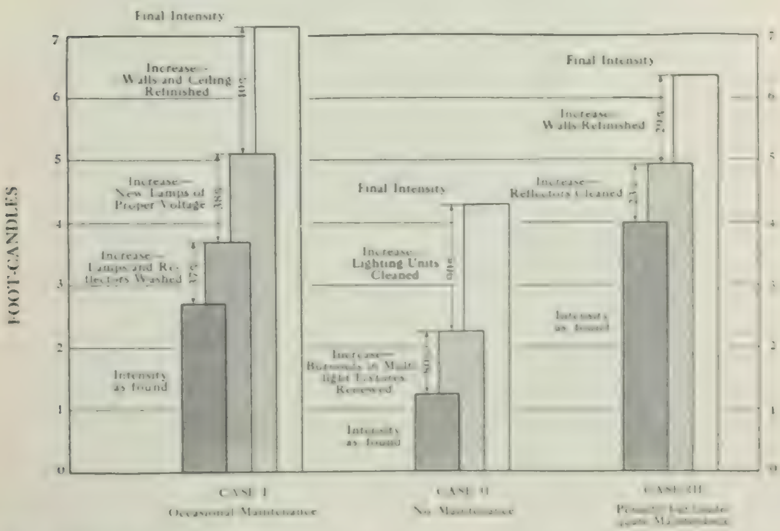


Fig. 2.—Chart showing the importance of prompt renewal of burned out lamps and systematic cleaning of the lighting equipment. These particular tests were on semi-indirect and indirect lighting systems.

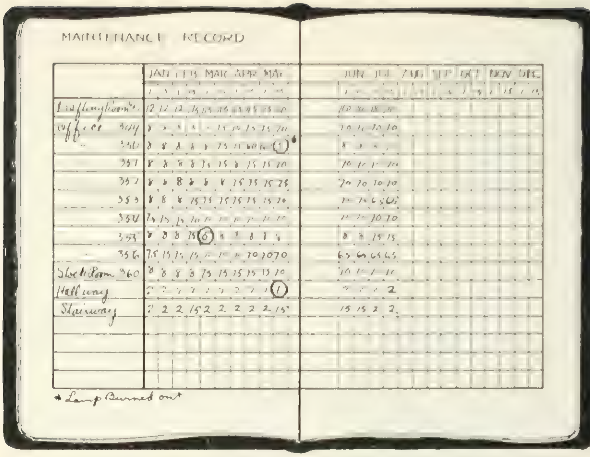


Fig. 3.—Lighting Maintenance Record.

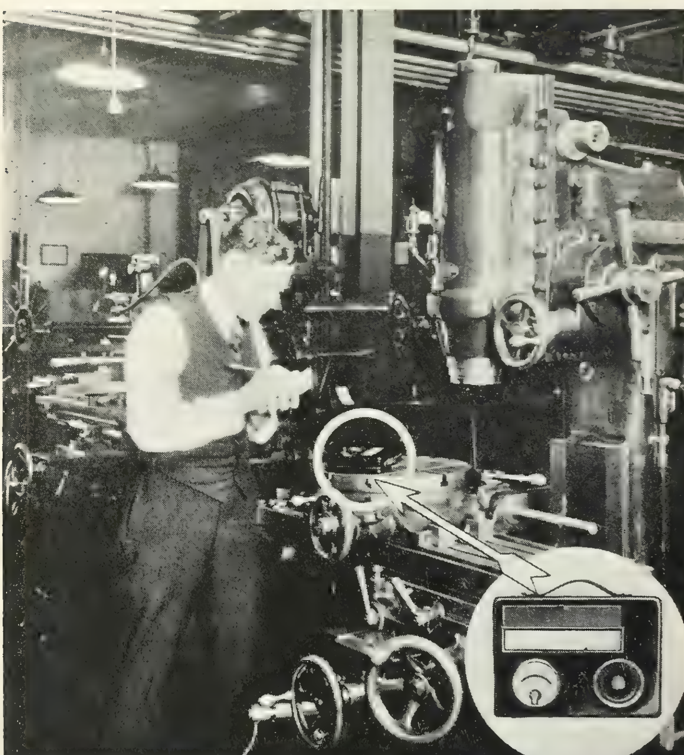


Fig. 4.—A survey of actual lighting conditions can readily be made with the foot-candle meter. This instrument is very useful in "checking up" a lighting system to see that it is being properly maintained.

When any inconsistency appears in the records an investigation is made and the remedy applied. The illumination in that establishment is never allowed to fall below 6 foot-candles without immediate correction. By measuring light actually delivered to the work the foot-candle meter automatically reveals the combined effect of all possible causes of depreciation. Ignorance of the magnitude of depreciation has often been the cause of inadequate maintenance. Soap and water cost less than gas and electrical energy.

Locating Switches and Controls—The switches which turn on and off the light in the entrances and halls of a building should be located near the points of entrance. Likewise switches which control at least one circuit of lamps in a room should be located near the principal points of entrance to that room.

In locating switches or control devices in factory and mill aisles, care should be exercised to arrange them systematically; that is, on columns situated on the same side of the aisle and on the same relative side of each column. This plan materially simplifies the finding of switches or control devices, by those responsible for turning on and off the light.

Control Parallel to Windows—The light from the lamps most distant from the windows will usually be required at times when the natural light near the windows is entirely adequate, thus making it advantageous to arrange the groups of lamps in circuits parallel to the windows. The advantage of this method is further apparent when it is considered that if the lamps are controlled in rows perpendicular to the windows, all lamps in a row will necessarily be on at one time, while a portion only may be required.

Notes on Rule 2—Avoidance of Glare.

Glare may be defined as any brightness within the field of vision of such a character as to cause discomfort, annoyance, interference with vision, or eye fatigue. Always a hindrance to vision, it often, like smoke from a chimney, represents a positive waste of energy as well. It is one of the most common and serious faults of lighting installations; the Code properly requires the shading of lamps in industrial plants to guard against glare.

Glare is Objectionable because (1) when continued it tends

to injure the eye and to disturb the nervous system; (2) it causes discomfort and fatigue and thus reduces the efficiency of the worker; and (3) it interferes with clear vision, and thus reduces the efficiency and in many cases, increases the risk of accident or injury to the worker. From both a humanitarian and a business viewpoint, the owner or operator of a factory, should be interested in avoiding glare, whether caused by daylight or by artificial light. On the other hand, in interpreting and enforcing the glare rule the inspector is not expected to insist upon what he may believe to be desirable practice in the given case; his duty is only to insure the absence of a condition which is prejudicial either to the health or to the safety of the worker.

If a simple instrument were available for measuring glare the task of the inspector would be comparatively easy. However, there are so many factors entering into the situation that it has not been found practicable to develop any instrument which will properly evaluate them all. To arrive at an intelligent judgment in any given case, therefore, the inspector must be reasonably familiar with the principal factors in or causes of glare.

CAUSES OF GLARE—There are five principal causes of glare:—

1. *Brightness of Source*—The light source may be too bright; that is, it may give off too high a candlepower per square inch of area.

A glance at the sun proves that an extremely bright light source within the field of vision is capable of producing acute discomfort. Light sources of far lower brightness than the sun, such for example, as the filament of an incandescent electric lamp or the incandescent filament of a gas lamp, may also cause discomfort, although the annoying effect is usually not quite so marked.

2. *Total Volume of Light*—The light source may be too powerful for comfort; that is, it may give off too great a total candlepower in the direction of the eye.

Too frequently glare is assumed to be entirely a question of the brightness of the light source; of equal importance is the question of its total candle-power. Experience has shown that a 500-watt lamp in a 10-in. opal globe, or a mercury-vapor lamp of an equivalent light output, hung 7 or 8 feet above the floor and a similar distance ahead of the observer will prove quite as glaring as the exposed filament of a 50-watt

incandescent lamp in the same location. The brightness of the opal globe unit is only a few times that of a candle flame, but its total candle-power and consequently the quantity of light which reaches the eye is altogether too great so that its effect is worse than that of the bare filament of lower candle-power, although the latter may have a brightness as high as 3000 candle-power per square inch. An unshaded window often causes glare, due, of course, to the large volume of light rather than to the high brightness of the sky.

3. *Location in the Field of View*—A given light source may be located at too short a distance from the eye, or it may lie too near the center of the field of vision, for comfort; that is, within too small an angle from the ordinary line of sight.

The 500-watt opal globe unit discussed in the previous illustration would seldom cause discomfort if placed, say 80 feet away from the observer, for at this distance the total quantity of light entering the eye would be only one one-hundredth of that received at 8 ft. Again, the same light source would probably be found quite unobjectionable at a distance of 8ft. from the eye provided this distance was obtained by locating the lamp 4 ft. ahead of the observer and 7 ft. above the eye level; in this case the lamp would scarcely be within the ordinary field of view.

The natural position of the eye during intervals of rest from any kind of work is generally in the horizontal direction, and it is desirable that during such periods the worker should be freed from the annoyance caused by glare. Glare is the more objectionable the more nearly the light source approaches the direct line of sight. While at work the eye is usually directed either horizontally or at an angle below the horizontal. Glaring objects at or below the horizontal should especially be prohibited. The best way to remove light sources out of the direct line of vision is to locate them well up toward the ceiling. Local lamps, that is, lamps placed close to the work, if used at all, must be particularly well screened.

4. *Contrast with Background*—The contrast may be too great between the light source and its darker surroundings.

It is a common experience that a lamp viewed against a dark wall is far more trying to the eyes than when its surroundings appear relatively light. A light background requires, first: that the surface should be painted in a color which will reflect a considerable portion of the light which strikes it, and second: that the system of illumination employed should be such as to direct some light upon the background. In many cases the ceiling appears almost black under artificial light simply because no light reaches it. With daylight, on the other hand, the walls of a room are often so well illuminated that they appear brighter than the work itself and this, also, is a condition which is not conductive to good vision. In general, a light tone for ceilings and high side walls and a paint of medium reflecting power for the lower side walls will ordinarily be found most satisfactory under both artificial and natural lighting.

Where strictly local lighting systems are employed, that is, where individual lamps are supplied for all benches and machines, and no overhead lighting is added, the resulting contrasts in illumination will usually be found so harsh as to be objectionable even though the lamps themselves are well shielded. The eyes of the workman looking up from his brightly lighted machine or bench are not adapted for vision at low illuminations; hence, if adjacent objects and aisles are only dimly lighted, he will be compelled either to grope about, losing time and risking accident, or to wait until his eyes have become adapted to the low illumination. Glancing back at his work, he again loses time while his eyes adjust themselves to the increased amount of light which reaches them. If long continued, this condition leads to fatigue, as well as to interference with vision, and to accidents. In other words, where local lamps are employed, there should also be a system of overhead lighting which will provide a sufficient illumination of all surrounding areas to avoid such undesirable contrasts.

5. *Time of Exposure*—The time of exposure may be too great, that is, the eye may be subjected to the strain caused by a light source of given strength within the field of vision for too long a time.

Where an operator is seated and his field of vision is fixed for several hours at a time, light sources of lower brightness and lower candlepower are required than where the operator stands at his work and shifts his position and direction of view from time to time. In the first case the image of the light source is focused on one part of the retina for considerable periods of time and is obviously more likely to cause discomfort and eye strain that when present for short periods only. Those who are forced to work all day at desks facing the windows are particularly likely to suffer from this form of glare.

RATING LIGHT SOURCES FROM THE GLARE STANDPOINT—It is evident that the first two factors mentioned as causes of glare, namely, excessive brightness and excessive candlepower, concern the light source itself, the third factor concerns its location in the field of view; and the fourth and fifth depend upon the conditions of its use.

In Table III a means of rating light sources (into Grades I to X) has been provided which takes into account both their brightness and their candlepower. Light sources in Grades I and II may be termed soft or well diffused; those in Grades VIII, IX and X are harsh and likely to cause glare. It is seen from Table III that a light source of high intrinsic brightness but of low

Fig. 5. Wherever local lighting is used it should be supplemented by some general illumination. Note the absence of glare and contrast between light and dark areas in this room as compared with Fig. 6 where there is no general illumination. In the above photograph although a local lamp is supplied for each machine, the individual sources of light are scarcely apparent because of the general illumination.

Figs. 6 and 7.—Adjoining rooms in the same factory. The upper figure illustrates a strictly local lighting system of the poorer sort. The lower figure illustrates a lighting system consisting of 150-watt bowl enameled lamps equipped with dome reflectors spaced 10 feet apart; the average illumination is 9 foot-candles.

candlepower,—for example, one that would be classified under the fifth line of the first column (less than 20 cp.—and 100 to 1000 cp. per sq. in.) has the same rating, Grade V, as a source of lower brightness but of greater total candlepower, (2-5 cp. per sq. in. and 500 total cp.) which falls in the second line of the fifth column.

TABLE III

CLASSIFICATION OF LIGHT SOURCES FROM THE STANDPOINT OF GLARE

Grade I indicates sources of maximum softness.
Grade X indicates sources of maximum harshness.

MAXIMUM VISIBLE BRIGHTNESS	TOTAL CANDLEPOWER IN DIRECTION OF EYE.				
(Apparent candles per sq. in.)	Less than 20	20 to 50	50 to 150	150 to 500	500 to [illegible]
	Grade	Grade	Grade	Grade	Grade
Less than 2	I	I	II	II	III
2 to 5	II	II	III	IV	V
5 to 20	II	III	IV	VI	VII
20 to 100	IV	V	VI	VII	VIII
100 to 1000	V	VI	VII	VIII	IX
1000 and up	VI	VII	VIII	IX	X

In accordance with the plan of Table III measurements of brightness and candlepower have been made on a number of light sources found in every day practice, both natural and artificial, and grades have been assigned to them as shown in Table IV. While engaged in his work, the inspector will, of course, find other light sources in use which are not included in the Table; however, from those which are given he should be able to estimate closely in what grades the others should be placed. In cases of doubt, it is, of course, possible to have actual measurements made to determine both the brightness of the lighting unit and its total candlepower. The unit can then be rated in accordance with Table III.

TABLE IV

SPECIFIC CLASSIFICATION OF LIGHT SOURCES FROM THE STANDPOINT OF GLARE AS DERIVED FROM TABLE III

NATURAL LIGHT SOURCES

(As seen through windows or skylights)

	Grade
Sun	X
Very Bright Sky	V
Dull Sun	III
Sun Showing on Prism Glass	IX

OPEN GAS FLAMES	II

INCANDESCENT MANTLE GAS LAMPS

	Mantles Consuming 2–5 cu. ft. per hr.	Mantles Consuming 5-8 cu. ft. per hr.	Large Single Mantle or Cluster 8-12 cu. ft. per hr.	Large Single Mantle or Cluster 12-20 cu. ft. per hr.	Cluster or High Pressure Lamp. consuming above 20 cu ft. per hr.
	Grade	Grade	Grade	Grade	Grade
Clear Glassware	V	VI	VII	VIII	IX
Frosted Globes	III	IV			
6-in. Opal Globe* 8-in. Opal Globe* 10-in. Opal Globe* 12-in. Opal Globe*	II I	III II	IV-VI III-V	V-VII	VI-VIII
Dome Reflector					
Mantle Visible	V	VI	VII	VIII	IX
Mantle not Visible	I	II	III	IV	IV
Bowl Reflector					
Mantle Visible	V	VI	VII	VIII	IX
Mantle not Visible	II	II	III	V	V
Totally Indirect*			I-II	II	III
Semi-Indirect Bowls*			II-III	II-IV	III-VI

*Where a range is given the best grade, that is the lowest, applies to globes that are evenly luminous, and the poorest to globes which have a decidedly bright spot in the center.

TABLE IV.—Continued.

ARC LAMPS

	Grade
Enclosed arcs, clear globes	IX
Flame arc, clear globes	X
Flame arc, opal globes	VII-VIII

MERCURY VAPOR TUBES	VI

CARBON AND METALLIZED FILAMENT INCANDESCENT LAMPS

8 c. p.	V
16 c. p.	V
32 c. p.	VI

TUNGSTEN FILAMENT INCANDESCENT LAMPS

WATTS	10-25	40-60	75-100	[illegible]	300	500-1000
	Grade	Grade	Grade	Grade	Grade	Grade
Bare Lamps	VI	VII	VIII	IX	IX	X
Frosted Lamps or Frosted Globes	II	III	VI	VII	VIII	
8-in. Opal Globes*	I	I-II	II-IV	IV-VI		
12-in. Opal Globes*			II-III	II-V	IV-VI	VII-VIII
16-in. Opal Globes*				II-V	IV-VI	V-VII
Flat Reflectors—Filament Visible	VI	VII	VIII	IX	IX	X
Dome Refls.—Steel or Dense Glass						
Fila. visible from working position	VI	VII	VIII	IX	IX	X
Fila. not vis. from working position	I	I	III	III	IV	VI
Bowl Refls.—Steel or Dense Glass						
Fila. visible from working position	VI	VII	VIII	IX	IX	X
Fila. not vis. from working position	II	II	III	IV	VI	VII
Dome Reflectors—Bowl-Enameled Lamps			IV	V	VI	VI
Semi-Enclosing Units*			III-IV	IV-VI	IV-VII	VI-VIII
Totally Indirect Lighting*			I-II	I-II	II	III
Semi-Indirect Bowl*			I-III	II-III	II-IV	III-VI

*Where a range is given, the best grade, that is the lowest, applies to globes that are evenly luminous, and the poorest to globes which have a decidedly bright spot in the center.

TABLE V

CHART OF THE FIELD OF VIEW

(Classification of Position of Light Source Which Takes into Account the Distance from the Eye and the Angle of the Line of Vision)

Height above Floor in Feet	HORIZONTAL DISTANCE OF LIGHT SOURCE FROM OBSERVER IN FEET															
	1	2	3	4	6	8	10	12	16	20	25	30	35	40	50	60 & up
6.5 or less	A*	A*	A	A	A	A	A	A	A	A	A	A	B	B	B	B
6.5 - 7	G	E	D	C	C	B	B	B	B	B	B	B	B	B	B	C
7 - 8	G	G	F	E	D	D	C	C	C	C	C	C	C	C	C	C
8 - 9	G	G	G	F	F	E	D	D	C	C	C	C	C	C	C	D
9 - 10	G	G	G	G	F	F	E	E	E	D	D	D	D	D	D	D
10 - 11	G	G	G	G	G	F	F	F	E	E	D	D	D	D	D	D
11 - 12	G	G	G	G	G	F	F	F	F	F	E	E	D	D	D	D
12 - 13	G	G	G	G	G	G	F	F	F	F	E	E	E	E	E	E
13 - 14	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E	E
14 - 15	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E
15 - 16	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E	E
16 - 17	G	G	G	G	G	G	G	G	G	G	F	F	F	F	E	E
17 - 18	G	G	G	G	G	G	G	G	G	G	G	G	F	F	F	F
18 - 19	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	F
19 - 20 & up	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

*Classified as A unless light source is so nearly above the head of operator as to be quite outside of field of view in which case classify as E.

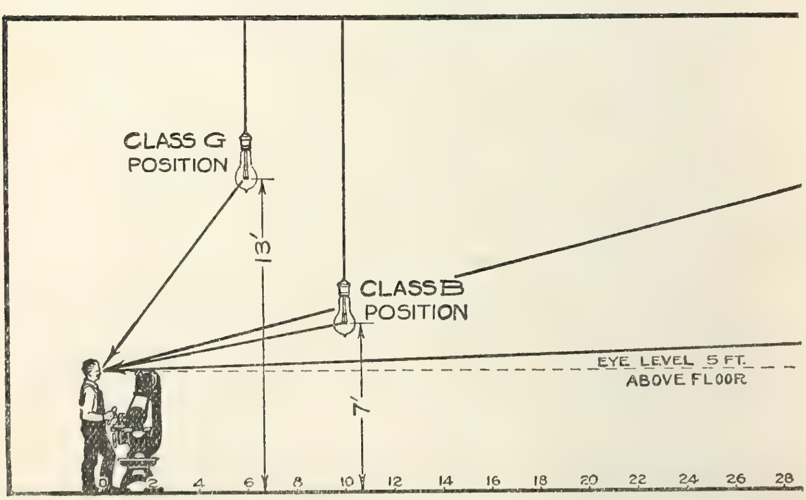


Fig. 8.—Diagram illustrating typical position given—

TABLE VI

SHOWING LIMITING GRADES OF LIGHT SOURCES PERMISSIBLE FOR VARIOUS SOURCES

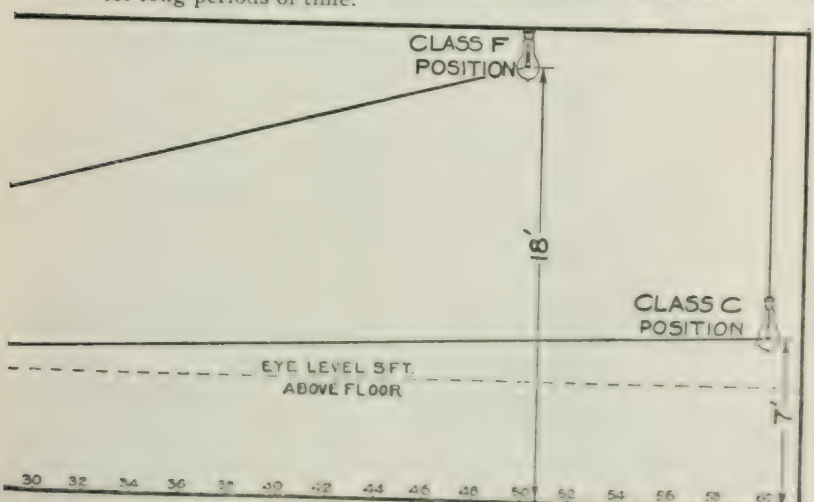
Classification of Position.	Space or work to be lighted.			
	Roadways and Yard Thoroughfares	Storage spaces, Aisles, Stairways, Handling Coarse Material	Ordinary Manufacturing Operations†	Offices and Drafting work & Certain Mfg. Operations*
	Limiting Grade	Limiting Grade	Limiting Grade	Limiting Grade
A	VI	V	III	II
B	VII	VI	V	IV
C	VIII	VII	VI	V
D	IX	VIII	VII	VI
E	IX	IX	VIII	VII
F	X	X	IX	VIII
G	X	X	X	X

BACKGROUND

Where the background and the surroundings are very dark in tone, a light source of one grade softer than that specified in Table VI may be required. Where the background and surroundings are very light in tone one grade more harsh than that specified in the table may sometimes be permitted.

†For the present the limits set in this table cannot be rigidly applied to portable lamps used for temporary work such as setting up machines, repairing automobiles, etc.

*Those operations in which workers are seated facing in one direction for long periods of time.



in the chart of the field of view, see Table V.

From a study of Table IV it will be observed that incandescent lamps equipped with reflectors which do not completely hide the light source have been assigned to the same grade as the corresponding sizes of bare lamps. It is true that the addition of a reflector somewhat increases the total candlepower in the direction of the eye and therefore the argument might be advanced that a 100-watt lamp with a flat reflector should be classified in Grade IX whereas the bare lamp is Grade VIII. On the other hand, from the standpoint of glare, the effect of the light background furnished by the reflector at least compensates for the increased candlepower which it gives; the rating is therefore kept at Grade VIII.

Charting the Field of View—It has already been pointed out that the distance between a light source and the eye, and its angle to the line of vision have much to do with determining how bright a light source may be used without discomfort. In Table V, which is a chart of the field of view, the possible locations of light sources are classified in seven groups, A to G inclusive, depending upon their distance from the eye and their proximity to the line of vision. Light sources in positions designated A, B or C, are close to the eye or close to the line of vision; hence they are most likely to be the cause of discomfort, and the greatest care must be exercised in their selection. In positions, F and G, on the other hand, the use of relatively bright sources is much less harmful.

Limiting Grades for Specific Installations—Table VI shows the harshest grade of light source which should be permitted within the field of vision for fixed conditions as to location of lamp, brightness of background, and character of work performed.

The grades named in Table VI are definitely limiting values and in each case the use of softer light sources is to be recommended; that is, where Grade IV is permitted, the installation of a lighting unit of Grade II or of Grade III will be conducive to better results as regards both accuracy of vision and eye comfort.

From Table IV the majority of bare incandescent lamps are seen to have a relatively poor rating; that is, most of them fall in Grades VII to IX, and it is evident from Table VI that Grades

VII—IX are never to be permitted in work rooms in positions A, B or C. That is, the use of bare incandescent lamps is prohibited in working areas except when they are located at considerable heights above the floor or when they are so placed as to be out of the field of vision. At the present time it will be found necessary from a practicable standpoint to delay the strict enforcement of this provision in a very few instances, particularly in the case of extension cord lamps used in temporary work, such as in setting up machinery and in repairing automobiles, etc.

It will be noted from Table IV that the sources of natural light, side and ceiling windows, usually fall in Grade IV. This means (see Table VI) that no mandatory rules are established as to the use of shades, awnings, etc., except in those cases where the sky is visible through portions of the sash in position A, that is, less than 6.5 ft. above the floor, or where the sun itself comes within the range of vision.

However, Grade II is the limiting value for light sources less than 6.5 ft. high, in offices, and other locations where the workers are seated facing in one direction for considerable periods of time. Hence, in these cases, to comply with the Table, the work must be so arranged that the employees are not required to face windows where the sky is visible through the lower sash; that is, less than 6.5 ft. above the floor.

Prism glass when so located as to catch the sun's rays ordinarily has a very much poorer rating than clear glass; hence, where it is used the installation of window shades or curtains should ordinarily be required.

The question naturally arises why if glare is so objectionable, should not all sources capable of producing glare be prohibited everywhere. The answer is that to attain a maximum softness of light sometimes entails a sacrifice in efficiency and an increase in operating expense. If a worker chooses unnecessarily to gaze directly upward at bright skylight or at an artificial lighting unit so located that it is not a factor in glare under ordinary circumstances, it is scarcely within the province of a code of lighting to protect him from the consequences.

How to Use Tables IV, V and VI—To determine whether a given lighting installation is within the glare limits specified, proceed as follows:

(I) Select what appears to be the most glaring light source within the field of view of any of the employees when at work. Measure the height of that light source above the floor and its horizontal distance from the worker.

(2) With the height and distance find in Table V how this location in the field of view is classified, Position (A, B or C) etc.

(3) With the classification of the position fixed from (2) determine from the proper column of Table VI the harshest grade of light source ordinarily permissible for this location.

(4) If surroundings are very light or very dark, apply a correction of one grade (plus or minus) to the value found in (3).

(5) From Table IV find the classification of the light source in use and compare with (4). (If the particular source is not listed, its grade may be estimated or may be determined by actual photometric measurements.)

Glare By Reflection—Another way in which glare is produced is by the reflection of light from polished surfaces in the field of vision. The difficulty experienced in protecting the eyes from this kind of glare is sometimes very great. The brightness of the image on the working surface is, of course, proportional to the brightness of the light source above it, and hence, one way in which to minimize this effect is to diffuse the downward light; that is, to use a bowl-frosted, or bowl-enameled lamp or an enclosing fixture, or to employ semi-indirect or totally indirect lighting fixtures. In some cases the light source can be so located that its reflection is directed away from, rather than towards, the eyes of the workers. The avoidance of highly polished surfaces in the line of vision is another good way to minimize reflected glare.

There are some instances, on the other hand, where sharp shadows and specular reflection from the materials worked upon actually assist vision. For example in sewing on dark goods the thread is much more easily distinguished when illumination is secured from a concentrated light source, such as a brilliant lamp filament, which casts sharp shadows and gives rise to a

Fig. 9.—Glaring light from unshaded local lamp which is a menace to safety and to vision and is one of the evils which the Lighting Code is expected to eliminate.

Fig. 10. Lighting an office by means of indirect units. Illumination approximately 6 foot candles.

Fig. 11.—Drafting room lighting using dense semi-indirect units and 200-watt lamps.

Fig. 12.—A yard lighting installation consisting of 150-watt lamps in shallow bowl reflectors, mounted 20 ft. from the ground. The units in each row are spaced 60 ft. apart, and the two rows are 30 ft. apart.

distinct glint from each thread. However, in these cases the light source must be particularly well shielded from the eyes of the worker.

Notes on Rule 3—Exit and Emergency Lighting.

The employer is to be held responsible for the proper lighting of passageways, stairways and exits, in so far as his premises are concerned; which means such parts of buildings, floors or rooms as are controlled by the employer, including entrances thereto, but excluding hallways, passageways and stairways giving access to other floors, or to spaces on the same floor, and used in common by the tenants of the building These latter shall be lighted by the party or parties in control of the building, in accordance with the Code, and the following provisions and interpretations thereof:

"Exit and Emergency Light-Sources" are to be understood as those artificial illuminants which are necessary only to make clear to the occupants or employees the regular places of exit, or to enable them to pass to and along safe exits with reasonable speed and assurance of footing. Such lighting is never assumed as being necessarily sufficient for the proper performance of regular working operations.

The circuits for exit and emergency electric lamps should be wired to be independent of the working lamps, back at least as far as the branch panel or distributing board, and should be separately fused, so that any failure of the regular working lamps through causes arising within that working space will not also cause failure of the exit, stairway, or passageway lamps.

No fuses smaller than those of the emergency branch circuits shall be used back of (that is, on transformer, meter or generator side of) such circuits, and no power machinery, portable extension cords or convenience outlets shall be on such emergency circuits.

The "main service entrance" may be interpreted to mean the entrance point (meter or distributing panel) of lighting feeders for the building, floor, loft or particular space in question. In gas lighting, it may be considered to be the main gas feeder for the building, or the main gas riser for the floor or loft in question. Where several factory spaces are grouped in the same building, each with its own exit or exits, the emergency electric circuits

for any one space are not required to run to the main building panel board or main switch nor are the emergency gas pipes expected to extend to the main gas meter nor to the building feeder from the street main, except as explained below.

Under specially dangerous conditions, where in the opinion of the recognized authorities the failure of the main and entire regular lighting supply would leave the employees without assured means of seeing the outgoing passageways, the exit and emergency lamps should be fed from an entirely separate source of energy, such as a storage battery, or, in case the regular lighting system is electric, from gas or other reasonably dependable illuminant. Under normal conditions, however, the phrase "separate supply" shall in electric service, be interpreted to mean a separate branch circuit which will afford lighting as long as transformers, generators or main lighting feeders are intact; and in gas service, interpreted to mean branch piping extending back to a sufficiently large feeder to insure a gas supply unless stoppage occurs near or outside of the main gas meter.

As indicated in the general requirements under Part I of this Code, the exit and emergency lamps should be lighted whenever artificial lighting is required in the work spaces.

It is the obvious intent of Rule III to insure reduction of accident hazard, and inasmuch as this end is as beneficial to the industrial operator or owner as to the State, the detailed interpretations of this order, for the various and sundry types and situations of working spaces, must be reached through mutual co-operation of the owner and the State authorities.

Fig. 13.—Lighting of steel rolls. Illumination provided by five mantle inclosed gas arc lamps, equipped with opaque reflectors.

Fig. 14.—Shirtwaist factory, sewing machine lighting. Illumination provided by single mantle gas lamps equipped with prismatic reflectors. Lamps spaced [illegible] feet apart with a clearance of 5 feet above working plane.

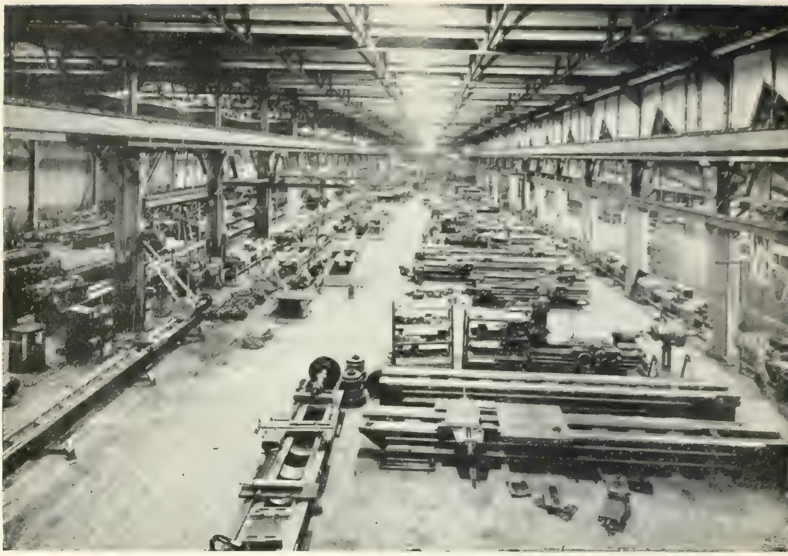


Fig. 15.—A plant where machine tools are manufactured, using mercury-vapor lamps spaced 20 feet apart at a height of 25 ft. above the floor; approximately 1-watt per sq. ft.

Fig. 16.—Laundry lighting—Illumination provided by five mantle gas arc lamps, inclosed type, equipped with diffusing glass globes.

PART III.

ADVANTAGES OF GOOD ILLUMINATION.

While the advisability of good natural and artificial illumination is so evident that a list of its effects may seem commonplace, these effects are of such importance in their relation to factory management that they are worthy of careful attention. The effects of good illumination, both natural and artificial, and of bright and cheerful interior surroundings, include the following:

1. Reduction of accidents.
2. Greater accuracy in workmanship, resulting in improved quality of goods.
3. Increased production for the same labor cost.
4. Less eye strain.
5. Greater contentment of the workmen.
6. More order and neatness in the plant.
7. Supervision of the men made easier.

While it is difficult to place a definite money value on the savings effected in increased production and improved quality, by good illumination, it by no means follows that such savings are insignificant or unsubstantial. The factory owner who ignores them neglects his own interests. Other items in the foregoing list, even more difficult to value definitely, are none the less real; taken together, they constitute a powerful argument in favor of the best available illumination in the factory.

The following estimate, conservatively based on practical conditions, gives an idea of the relative costs of good illumination by artificial means, and of labor, in the factory.

Assume that the lamps are so spaced that one 100-watt incandescent electric lamp will take care of one operator; that in this particular case the lamp burns on the average two hours per day, three hundred days per year; that the life of the lamp is one thousand burning hours; and that the operator works eight hours per day, 300 days per year.

Investment:	
Cost of lamp (list price)	$1.10
Cost of enameled steel reflector (list price)	2.50
Cost of wiring per outlet	8.00
Total Investment	$11.60
Cost of Operating per Annum:	
Interest on Investment, $11.60 at 6%	$ 0.70
Depreciation on reflector and wiring at 12½%	1.31
Renewal of lamp $\frac{600}{1000}$ x $1.10	6.06
Cleaning, at 3¢ per cleaning, two per month	0.72
Energy at 5¢ per Kw-h	3.00
Total Annual Cost of Maintaining Good Illumination:	
Per man per year	$6.39
Cost of Labor: Annual Wages per Man per year	
Eight hours at 45¢ per hr.; 8 x 300 x $.45	$1080

If an operator, because of the good illumination, saves—in more production, or better quality of product—the equivalent of only three minutes per day for 300 days, he will offset the annual cost of the illumination. Good illumination is, relatively speaking, inexpensive, and its introduction and maintenance are good investments on the part of the factory owner.

These estimated figures, illustrating the low cost of good lighting compared with the cost of labor, also illustrate how large may be the losses unconsciously sustained by the factory owner from the use of a poor lighting system. An operator losing, say, 30 minutes per day, loses more than $60.00 per year, or about ten times the cost of giving him good illumination.

The factory owner, when approached by the gas or electric lamp salesman, should weigh carefully any argument in favor of a change in his lighting system which is based solely upon a resultant saving in energy consumption. The example given above shows how greatly the gain in increased output, due to good lighting, overbalances any possible saving in energy consumption effected by changes in the system of illumination. If the proposed new system sacrifices anything in the quality of illumination, or if it merely substitutes one inadequate system for another, it should be rejected, and the factory owner should insist that if his lighting installation is changed, the new system must meet the requirements of good illumination even though this involves the

consumption of more energy than before. First a good lighting system, and then as much economy in energy consumption as is consistent with the illumination requirements—such a policy is the wise one for the factory owner.

Accident Insurance Costs:

Compensation insurance premiums for a given plant are based on the amount of the payroll, and the rate is determined by the accident experience of a given industry, modified by the experience of the particular plant under consideration. With a rate of one per cent the annual premium in the case of 1000 employees at an average wage of $40.00 per week would be $20,800.00.

An insurance carrier might pay the claims resulting from two accidents per month (on an average) in this plant, and meet his own overhead costs, and still have a slight margin of profit. An experience of three accidents per month, one-third of them due to poor lighting (a not unlikely event), would probably leave the insurance carrier no option but to increase the rate by, say, 50 per cent. The premium would then be $31,200—an increase of $10,400. If the lighting costs only $3.00 per employee or $3,000 per year total, the owner's annual expense for poor illumination actually amounts to $13,400—of which $10,400 is required by the insurance company to meet accident claims. An expenditure of $6.00 per year per employee for lamps and energy might save a large portion, if not all, of the latter amount.

DISCUSSION

E. L. Elliott: This is a subject in which I am particularly interested. Formulating a satisfactory lighting code is not an easy matter. The difficulty lies in getting a code that can and will be enforced by those charged with the duty, and which will actually prevent the most serious abuses of industrial lighting, and yet work no hardship upon the manufacturer. If a list of exact rules is laid down it becomes difficult to intelligently enforce them; and if enforced unintelligently they may become sources of great annoyance to the manufacturer. If, on the other hand a few broad principles are laid down—as that "adequate lighting shall be provided"—the question of what constitutes adequate lighting in any given case may give rise to very serious differences of opinion between the enforcement officers and the manufacturer.

So far as state regulation of factory lighting goes it can concern itself only with the safety and health of the employee; whether or not it is such lighting as will enable the worker to turn out his maximun output is entirely beyond the state's interest and jurisdiction. The state can of course advise, as far as it likes, but no one is bound to respect its advice. In regard to safety, the provisions of the code as reported seem to meet the requirements satisfactorily. In respect to health, there is but one point on which statuory regulation can touch, and that is glare. It is sufficiently established that glare from modern light sources may injuriously effect the eyes, and from that the general health. To prevent such injury without necessitating the use of some particular form of light-source or accessory is a legitimate function of law. This can be accomplished in very practical manner by limiting the intrinsic brilliancy of luminous surfaces that are used within a specified distance from the working plane, or floor. This can be done by a very simple specification, which will cut out the use of bare incandescent and arc lamps, and still require no particular kind of globe, shade, or reflector.

Louis Bell: There are very many interesting points in this report. One of them has just been referred to, the question of trying to specify a glaring lamp of unspecified size merely by its intensity per square iinch. I have thrashed over that complete phase of the subject with great elaboration in connection with the Massachusetts code, and there is certainly in addition to the very plain connection between specific brilliancy and glare, a connection between, so to speak, flux and glare, mass illumination and glare; in other words, a condition of candle power per square inch, perfectly intolerable with a five hundred watt lamp, is harmless with a fifty watt, and that is one of the very troublesome things that we have had to deal with.

I think that the tables which the report gives come nearer to taking due account of these variables than anything that has yet been produced. They look complicated but are not.

With respect to the question of required illumination, the main thing is to set a minimum, no matter whether you actually measure the illumination with an accuracy of ten per cent or twenty-five per cent. If you are sure that it is over the minimum,

you are safe. To secure that minimum is the main thing. After a manufacturer finds that he has to provide the specified illumination, he generally provides much better illumination than he did before, but the fellow that the code is after doesn't care what illumination he gets if his people can only be kept at work, and the work not actually stopped.

I am reminded of what one manufacturer told me, a man who had a floor of four hundred by one hundred forty feet. The only means of exit was a door at each end, and the only means of emergency lighting was a kerosene lantern hung inside each door.

I asked this man how long it would take his people to get out, in case of need and he responded, "I'm damned if I know and I'm damned if I care."

That particular sort of fellow we want to get after with the code, and the only way to get after him is to put on an irreducible minimum and trust the factory inspector to see that minimum provided with the general direction to the inspector, "Put yourself in his place when you stand by the workmen and see the conditions under which he works."

E. P. HYDE: I am interested in the table giving the classification with respect to glare. I am gratified to see that not only brightness but also luminous flux is taken into consideration. Some eight or ten years ago when there was much discussion of this question in the London *Illuminating Engineer* we performed, at Nela Research Laboratory, a very simple experiment which showed the importance of the total luminous flux on the glare of a source of definite brightness.

A broad source was focused by means of a short focus lens on the cornea. The observer focused his eye on the lens which, except for errors in the lens, appeared as a large source of uniform brightness. Under these circumstances the glare was painful to each of a half-dozen observers. When, however, the lens was stopped down by means of a diaphragm, so that the total flux entering the eye was reduced without any change in the brightness of the source, the observer was able to view the source without any great discomfort. This experiment shows conclusively that not only the brightness but also the total flux of light entering the eye played an important part in determining glare.

This element has been duly considered in the table referred to above, but there is one question which I would like to ask. It may be that it is answered elsewhere in the report, but if so, it has escaped me in listening to the reading of the report by Mr. Stickney. I note that the various illuminants are graded according to brightness in candles per square inch and according to the total flux. I would like to ask if this rating was made on all lamps at the same distance? A 1000 watt lamp placed at a great distance would not be any more glaring than a 25 watt lamp placed very much closer. I would like to ask whether this element has been duly considered? Obviously in a rating light source with reference to glare it is necessary to take into consideration the distance at which the source will ordinarily be seen as it is used.

S. G. HIBBEN: As a member of this Committee, I might unofficially report one thing that was discussed, more as a matter of nomenclature. This is important because the factory inspectors are, as you know, men who are anxious to learn but who do not have the lighting experience that we may possess and do not converse in the illuminating engineering vocabulary, therefore must be helped in using the most simple and most non-mistakable terms.

One word (Mr. Harrison introduced this expression I believe) *i. e.*, "intensity," is an unfortunate way of explaining illumination values to the inspector or the customer. Intensity immediately suggests to the casual listener an idea of something disagreeable, sharp, as we speak of intense pain, intense heat, or intense pressure. It is entirely logical to use merely the word "illumination," or perhaps "illumination value," and then say "the illumination is 5 foot-candles," just as we would say "the weight of a brick is 2 pounds"—not "the intensity of the weight is 2 pounds." I regret the insertion of the word "intensity" in a code of this kind because psychologically it is often misinterpreted.

E. Y. DAVIDSON, JR.: I am very glad to see that the Committee has reported, the factors which determine glare. In my opinion we are approaching closer to proper limits. I think the Committee has used forethought in Table IV in giving limits for the glass enclosing globes, semi-enclosing units, totally indirect lighting,

etc. In view of the fact that glass enclosing globes vary in absorption from ten to forty or fifty per cent, and also because they will vary from being perfect diffusers to diffusers which are not diffusers at all, that changes the problem entirely.

I would like to know, however, for my own personal satisfaction, why three classes were given for total indirect lighting. I can realize that there would be a great difference in increasing the size of the globe when a ceiling had a glossy finish, so that the reflection of the lamp were occasioned, if we take into consideration the unit suspended from the ceiling, and the size of the lamp.

Also in Table III, I believe it would be interesting to know how it was determined to designate different enclosing globes as to their brightness and their candlepower and the direction of the eye, according to the letters that are given. What were the factors in making that gradation?

WARD HARRISON: In response to Dr. Hyde's question, Table III was intended by the Committee to represent as Mr. Stickney put it, the ability of various light sources to produce glare if they had equal change, equal space, an equal angle to the line of vision, the same distance from the eye. That was the first consideration. The second was the location of the light source with respect to the person working under it, whether close to him, far from him, or nearly over his head. The third was what sort of application does the work require, whether the operator faced one position for a long time and used his eyes looking at small objects or whether he simply had to walk around the room and shovel ashes.

Now, naturally the light source which had less than two candlepower per square inch, and less than twenty candlepower was given a very good rating in this case and one which gave more than five hundred candlepower per inch, was given the very worst rating.

Then all grades between that and the remaining thirty possible locations in the table were assigned grades by the Committee, which in their opinion represented approximately an equitable distribution, as a result of such experiments as have been reported from time to time.

In Table V (a chart of the field of view), you will see there is specifically taken care of the points which have been raised; namely, if the light source close above your head was less than six and a half feet and if it was just a short distance ahead of you, say, three, four, five or six feet, that position was put in Class A. That is the position most important to watch from the standpoint of avoiding glare. If it was higher up or more than sixty feet from you, where it was given a position where almost anything would be passed, it was put in Class G. If you walk into a shop and see what appears to be a glaring lamp and from the Table V you see it is between seven and eight feet above the floor in front of the workman, you put it in Class D.

Turn to Table VI and in the space used for ordinary manufacturing we must have Class A lighting. In an office such a bright light would not be permitted. If the height is thirteen feet and it is still eight feet away, it would be Class G.

As to the reason for classifying indirect lighting in groups one, two and three, depending upon the light source, I think you will agree; for instance, if we had indirect reflectors shining against that wall before us and they were equipped with thousand watt-lamps, no doubt the brightness of the wall might be so great as to be annoying, whereas if they were illuminated by one hundred-watt lamps, which would be more likely, the brightness would not be so great. I think it is very possible to have low-ceilinged-room lighted to such intensity by indirect lighting as to be unsatisfactory for instance in a hospital ward.

As to the question of putting light sources in Grade V Table III, in one case a lamp with less than twenty candlepower, and the other extreme less than five candlepower, per square inch, and then a total intensity of more than five hundred candlepower—I think that that is rather hard to satisfy oneself as to its reasonableness unless you perform the actual experiment. If you take the thousand-watt lamp and hang alongside it a bare fifteen-watt lamp, and then look at the two and decide which is the more annoying, I think you will find that you will agree with the table, and perhaps will put even more emphasis on the total flux and less on brilliancy.

G. H. Stickney: Speaking as a member of the Committee in the absence of the Chairman, it is gratifying to note the widespread interest as evinced by the discussion. As might be expected, some questions were raised which have been carefully considered by the Committee, and most of these have been satisfactorily explained. I need only touch on those points which seem to need additional comment.

The Committee has endeavored to be as fair and reasonable as possible, and avoid unnecessary or questionable restrictions. I am thoroughly convinced of the superiority of the new rule on emergency lighting. There was danger of the old rule being interpreted in too drastic a way. For example, there are many small one story workshops where but few people are employed and where night work is infrequent.

Failure of the artificial light is not likely in such cases to result in dangerous conditions. It is, therefore, neither necessary nor reasonable to require the same precautions as would be necessary for a crowded workroom on the tenth floor in a congested district. It would therefore be unfair to impose such a burden. The new rule mitigates this condition.

Mention was made of variation in intensity measurements on the order of 60 per cent. Of course, such errors can be made with the finest instruments. They would not seem to me to be justifiable with the roughest. There would seem to be no excuse for errors of more than 10 per cent, if reasonable care is exercised. It is undoubtedly true that many state inspectors are not sufficiently trained to insure accurate measurement. Their decisions are usually subject to appeal, and if an inspector makes a few mistakes, a correction is likely to be applied.

Fortunately, efficient manufacturing requires a better standard of lighting than can be demanded on the score of safety, so that when the economics are understood, there is not likely to be much of a tendency to encroach on the limits set by the code.

Education as to the advantages of good lighting is certain to make the codes easier of enforcement, and there appears to be a tendency on the part of state officials, to take advantage of various means of promoting education. The use of the term "intensity"

with reference to the strength of illumination, has been objcted to before in other connections. Perhaps the Committee on Nomenclature and Standards can suggest a better term.

In closing, I want to express the regret that I know Mr. Marks feels in his inability to be present at this discussion. He initiated this activity in the Society, and has continously led it as Chairman of the Committee, frequently at the sacrifice of his own personal affairs. The Society and country are certainly indebted to him for the splendid accomplishment.

ILLUMINATING ENGINEERING FACTORS IN ELECTRIC SIGN DESIGN*

BY C. A. ATHERTON**

Electrical sign manufacture in the past has followed largely empirical standards. The many great successes that have been achieved, have not been unmixed with a fair proportion of installations which have failed to produce the best effect obtainable with the materials available. In the hope of contributing to the illuminating engineering basis which should supplement the artistic and spontaneous genius without which there could be no such displays as Times Square, New York City, presents, this analysis is presented with some fundamental though limited data.

The effectiveness of an electric sign depends upon three essential characteristics. The first is the power to gain attention—that is, its attracting power. The second is the power to make itself understood, to be read, or deciphered—its legibility. The third is the power to impress its message into the minds of those whose attention it has caught (and who have been able to read it),—its selling power.

This paper is devoted to an analysis of some of the factors that affect the attracting power and legibility of exposed-lamp electric signs.

Legibility depends upon the visual acuity of the observer and the degree of openness or separation of the members or strokes of the letters. The degree of openness of a letter depends upon the shape of the letter and the width of the stroke, which in its turn, may be made of a single, a double or many rows of light sources. But also the apparent width of the line of light from a row of light sources is not a constant. In any given sign, it becomes wider, thus filling up the spaces of the letters and making them less legible and more blurred when higher intensity and brighter and more closely spaced light sources are used; it is wider (apparently) as the distance at which it is viewed increases.

* A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

** Engineering Dept., National Lamp Works of the General Electric Co., Cleveland, O.

and becomes narrower as the brightness of the surrounding parts of the same sign or other nearby signs and as the general illumination of the district where it is displayed are increased. It is affected by atmospheric conditions and is not the same for the various colors of light.

Ease of reading depends upon the pattern of the letters, the finish and color and spacing of the light sources, and the mechanical construction of the sign letters, whether they be made with or without a trough, whether the face be clean and white, etc.

A sign at a given distance is legible, as we use the term, when a person who has average eyesight and who is unfamiliar with the name, message or publicity pattern characteristic of the institution represented, can read the sign correctly the first time he sees it at that distance.

The lettering of a sign will cease to be legible, as the observer goes away from it, at some point where the angle at his eye subtended by two parts of a letter becomes so small that the eye cannot resolve them and the space between them appears to be filled up. An angle of one minute of arc is commonly accepted by opthalmologists as a convenient and safe measure of this angle for a pair of average eyes.*

For illustration, a small sign which was erected and tested in which plain Gothic letters were used (because they are the most open and legible) is taken. Fig. 1 shows this sign as it would appear if the strokes were single thin lines. The spacing which will first become filled up due to the failure of his eye to resolve them, as the observer goes away from the sign, are indicated by the small arrows. It is obvious that long before the angle at the eye subtended by the topmost and bottommost lamps is one minute of arc, or apparently all one point of light, the N will have become indistinguishable from an H and the E from a B, etc. When this happens, any two points on a letter, which at that distance subtend an angle at the observers eye of one minute of arc and are therefore at the limit of the resolving power of the eye, will have a distance between them which is a fractional part of the height of the letter. In the case of the

* For a physiological explanation of this phenomenon see "Design of Illuminated Signs" by Arthur H. Ford, TRANSACTIONS I. E. S., Vol. IX, p. 445. In these experiments, light sources of an intensity lower than are common practice now were used.

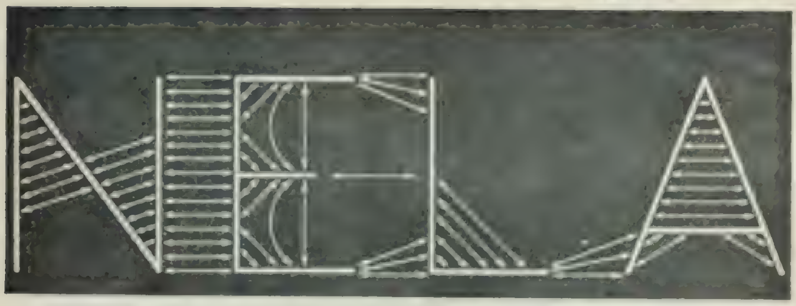


Fig. 1.—Small arrows indicate spaces between strokes which become blurred as the observer goes away from the sign.

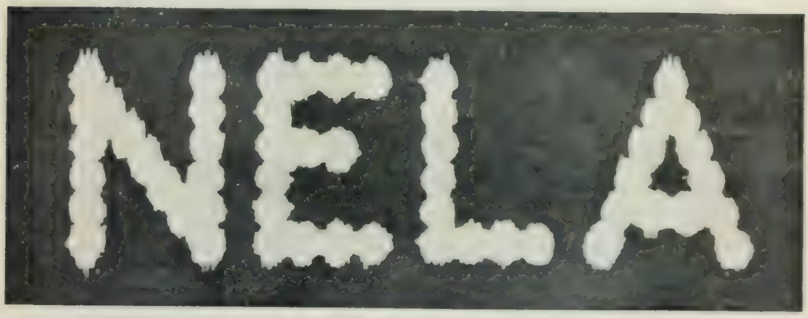


Fig. 2.—The appearance of a 30 inch letter sign, with [illegible]-watt lamps on six inch centers when viewed at 700 feet. If the paper is held at nineteen feet from the eye the letters will appear in true size.

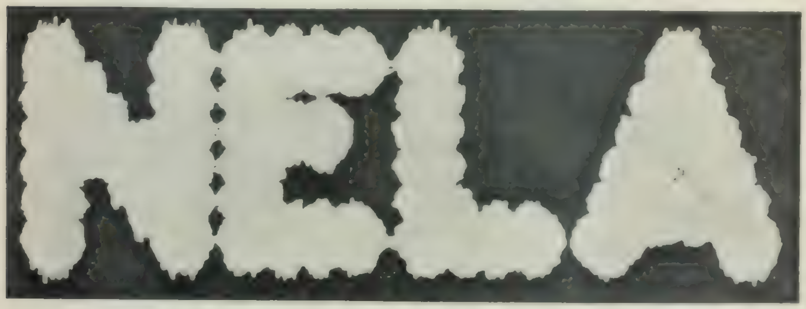


Fig. 3.—The same sign when viewed at [illegible] feet or the same sign with [illegible]-watt lamps in place of the [illegible]-watt lamps when viewed at [illegible] feet.

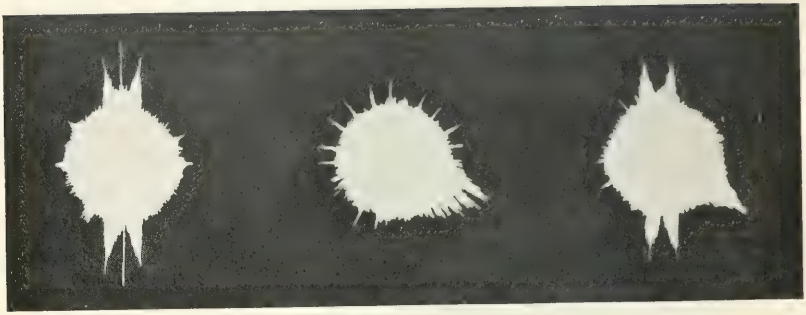


Fig. 4.—Typical spots drawn by three observers.

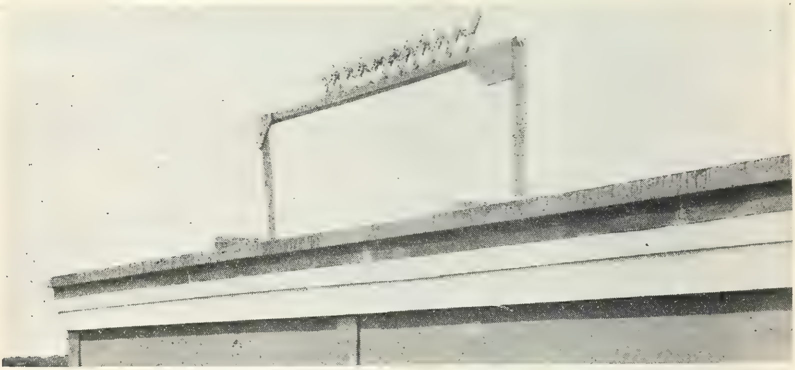


Fig. 5.—Pantograph device, used in Test No. 1.

letter E, this is obviously 0.5 H, in the N it is less; perhaps 0.3 H, etc. In the nomenclature of this analysis, these are the critical dimensions of these letters.

There is also a critical dimension for the entire word (or words, in case of a phrase) which ordinarily is less than the largest and more than the smallest of the various critical dimensions of the letters, assuming that the word is more or less familiar to the observer and that he need recognize a part only of the letters in order to read the entire word.

If the sign of Fig. 1, the letter height of which is 30 in. has a critical dimension of 0.4 H or 12 in., it will cease to be legible when two points spaced 12 in. subtend an angle of less than one minute of arc at the observers eye. This becomes so at distances of 3400 ft. and more. This then would be the limit of legibility for this sign if the letter strokes were lines of negligible width but always visible.

The letter stroke, however, is never of a negligible width. It may purposely be made wider by the use of two or more lines of lamps, in order to give the lettering a heavier and more substantial appearance. This would in itself cause the critical dimensions and consequently the limit of legibility to be reduced. But even if a single row of lamps is used the line of light has an appreciable width.

It was found in early observations that signs become illegible at distances much less than might have been expected if the critical dimensions of the letters had been measured from the center lines of the lamps.

The sign in Fig. 1 when equipped with 10-watt lamps, has an appearance somewhat like Fig. 2, when seen at 700 ft. The critical dimension now is about half what it was in Fig. 1. If the letter strokes appeared of this relative width at all distances, the limit of legibility would therefore be half what was figured when the stroke was considered as a fine line, or for this sign, about 1700 ft.

As the distance to the observer was increased from 700 ft., the appearance became rapidly less clear. At 1300 ft. it was very difficult to read, it looked like Fig. 3. The critical dimension

had become very nearly zero, while still the outer shape of the word was distinct. For this specific sign, the legibility limit came at less than 40 per cent of the theoretical maximum.

The effect of higher intensity light sources was then tried in the same sign. Seventy-five-watt lamps were installed and at 700 ft. it was estimated that the sign was legible with the same effort as it had been at 1300 ft., when eqipped with 10-watt lamps. It looked, therefore, like Fig. 3 except that the whole sign was nearly twice as large. It had a legibility limit of less than 20 per cent of the theoretical maximum.

If the line of light from a row of light sources varies in width as these observations indicated, increasing with the intensity and brightness of the sources and also with the distance at which it is viewed, a spot of light from a single source must also vary likewise. The single spot was, therefore, taken as the basis of study and the following tests made to determine the laws that govern its apparent size.

For convenience of discussion, the spot of light that appears uniformly bright when a light source is viewed at a distance, is referred to the plane of the light source where it has, by projection, concrete dimensions. Around this spot there are streamers and halos and rings, none of which are included in what is here called the spot. The spot itself is very irregular in shape and never twice alike but always has the appearance of a circular disc with a jagged perimeter. When the diameter of the spot is mentioned, the diameter of a circle whose area is equivalent to that of the spot is meant.

For a clearer visualization of what is meant by the spot, typical spots drawn by three observers are shown in Fig. 4. While the spots for any observer vary slightly from time to time, they are nearly enough alike so that if drawings were made of a large number of them, they would be easily devisible into groups according to the observers. As would be expected, when the observer's head is tilted sideways, in a plane perpendicular to the line of sight, the spot tilts with it, and when more than one light source is included in the field of vision, the spots from all of the sources are identical in shape though not necessarily in size.

Test No. 1.—

On the first attempt to measure the size of the spot of light, a series of lamps were placed on a pantograph device (See Fig. 4). The observer at a distance signalled to have the lamps brought more closely or separated more widely until they

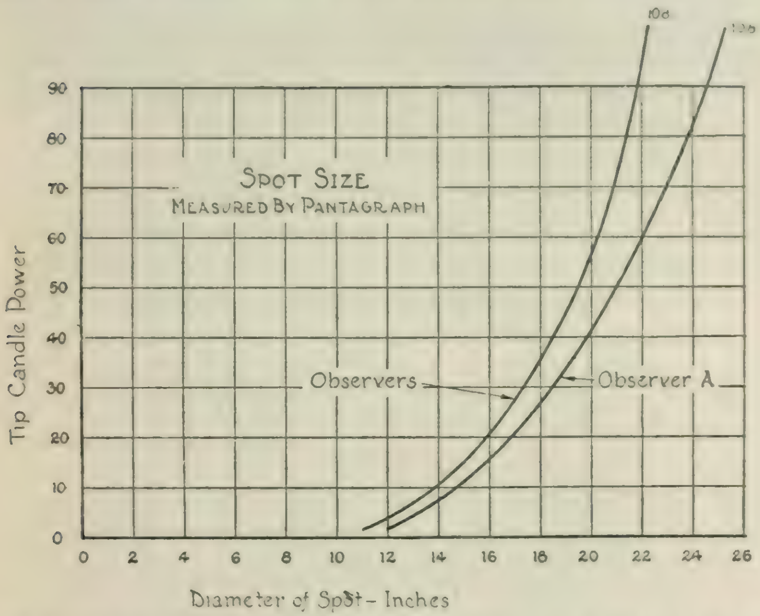


Fig. 6.—Spot sizes measured by means of the Pantograph Device against a dark background. In this test there were several lamps in a line and the size of any one of them would therefore be affected by the presence of the others.

had the appearance of just touching. The distance of separation of the light sources was measured and plotted against the tip candle-power of the lamps as shown in Fig. 6. Though this experiment gave little data as to the exact size of a single spot, it seemed to justify the first conclusion that the spot size varied with the intensity and brightness of the light source.

Test No. 2.—

The question then arose as to whether the spot of one lamp alone would appear the same as a part of the line of light from a series of lamps. In the next experiment, therefore, only one light source was used. A gas-filled lamp was horizontally mounted on a frame work (See Fig. 7) at about the level of the eye. About

18 in. away and on a horizontal level with the light source, was located a box enclosing a lamp. A circular bond paper window formed a diffuse disc of light. The illumination of the circular window or disc was reduced to a degree, where it could just be clearly and distinctly seen under all of the conditions of the test, the most severe of which was in comparison with a clear 100-watt gas-filled lamp. Precautions were taken to prevent the light source from illuminating the frame work and the near ground. This was done by enclosing it in a slightly conical black tube open at the front. The conditions were therefore a comparatively black background and surrounding field and a single light source. The observer walked forward and back from 50 to 250 ft. from the light source and measuring disc to a position where the spot of light appeared to be of the same size as that of the disc.

The variation of size of spot at different distances for a ten-watt lamp, as measured by this method, and the relationship between tip candle-power of various lamps and distance to the observer for a constant size of spot is given in Fig. 8. On two consecutive nights, two distinct curves for the same lamps were obtained. On the first night, the sky was cloudy, and on the second night the moon was very bright. The variation in the two curves is probably due to the relatively brighter surroundings on the second night, or to some atmospheric change.

Test No. 3.—

It was then thought probable that the calibration disc did not register a true size; it too might seem larger or smaller dependant upon its brightness and the intensity of illumination and the distance to the observer. To test this possibility, a point was found at which the disc and the open light source (a 50-watt gas-filled lamp) appeared to have the same size. The illumination on the disc was then decreased, the observer watching all the while and, up to the time that the disc ceased to be light enough so that it could be clearly distinguished, it apparently became continually smaller as it became dimmer.

This variation opened a new phase of the problem; it indicated that it was not only comparatively bright objects such as an incandescent filament, but relatively dim objects, things which are very close to the limit of visibility, that appear to

Fig. 7.—Apparatus used in Test No. 2. The light source is located inside the conical tube which was necessary in order to prevent the illumination of the frame work and fore ground. The tube held before the observers eyes was used to eliminate disturbing lights on the sides and also to prevent a subconscious tendency on the part of the observer to check his first reading position without an exact reference to the size of the spot. In making these readings, a point was always found at which the disc was distinctly larger than the spot, and the position was found at which the spot was distinctly larger than the disc. The distance between these readings was occasionally as much as 20 per cent of the total distance to the spot and disc.

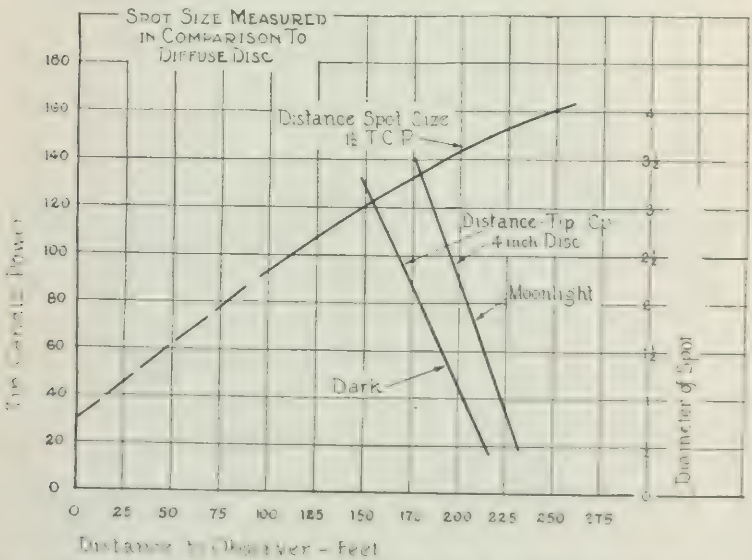


Fig. 8.—Spot size when measured in comparison with a uniformly bright disc. The two slightly diverging curves represent the different distances at which a number of lamps of different tip candlepower appear to have the same size of spot. In each case a four inch disc was used as a measure and the two curves were obtained on a dark and a moonlight night respectively. In the other curve the disc was changed and one lamp (1.5 tip candlepower) only was used. The distance at which this lamp had the same size of spot as the dimly lighted disc was measured. The dimensions are in terms of the apparent size of the disc spot and, therefore, are relative only.

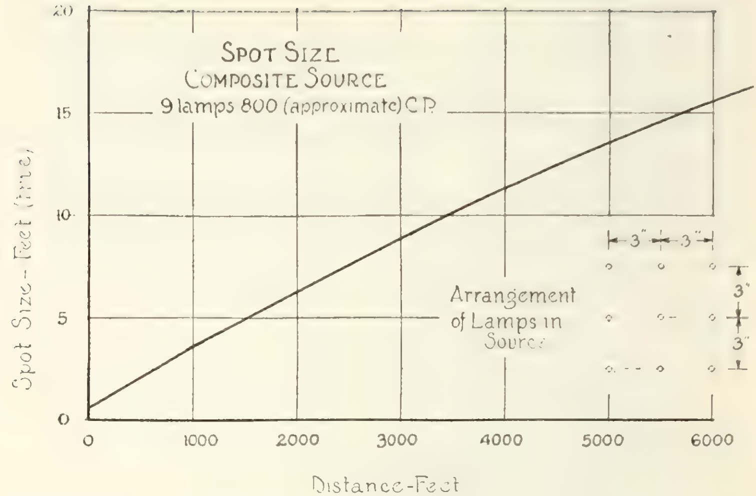


Fig. 9.—Size of spot of light from nine closely grouped lamps with a total candlepower of approximately 800.

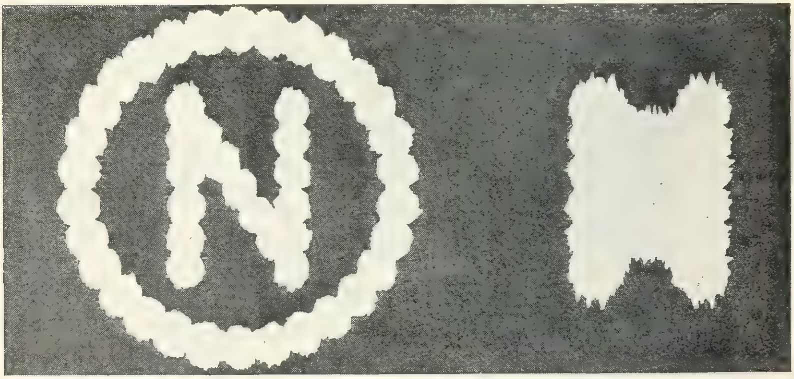


Fig. 10.—The effect of the border illumination in reducing the size of spots and increasing legibility.

change size according to their intensity, and that they do this, even when located at a very small angle from other objects, whose brightness may be a great many times greater. Also that the size of such an object not only increases but actually doubles within the range of what may be called a dim illumination.

It is seen then that the apparent size of any object which is located in a dark field depends upon the intensity and brightness of that object, no matter whether it be so dim as to be barely visible, or so light as to be dazzling and also upon the distance from which it is observed. Another effect of this test was to show that the values of spot size in the curves of Fig. 8 were relative only.

Test No. 4.—

It remained, therefore, to determine the exact size of a spot of light. It was felt that the result would be more definite if larger dimensions were taken. Consequently, nine lamps having a total beam candle-power of 800 were located in the center of the experimental sign board. They were mounted in a square 6 in. each way. A series of small lamps were located at 1-ft. intervals on a horizontal line through the center of the square. By counting the small lamps not obscured by the spot, It was possible to estimate the size of the spot up to distances of a mile and a quarter. A curve showing this variation is given in Fig. 9. These are, so far as is known, true spot sizes for the one condition, that is for a single large light source (made up of nine lamps) in a dark sky.

Test No. 5—

The procedure in test No. 4 could not be applied satisfactorily to single lamp source or sources of lower intensity, so the following plan was tried. Along the parapet of the building, a row of very low intensity light sources was placed. These were spaced on six inch centers and extended in a line 20 feet long. At a distance, they had the appearance of a dim but fairly continuous reference line. On the frame work behind the parapet, by means of a rope and pulley, the light source under test was raised and lowered according to signal from the observer. At a point where the middle of the reference line seemed to become

just tangent to the base circle of the spot, the light source was stopped and the vertical distance between the reference line and the center of the lamp, or the radius of the spot was measured.

By means of this procedure, more consistent data were obtained. The shape of the spot size—distance curves was the same

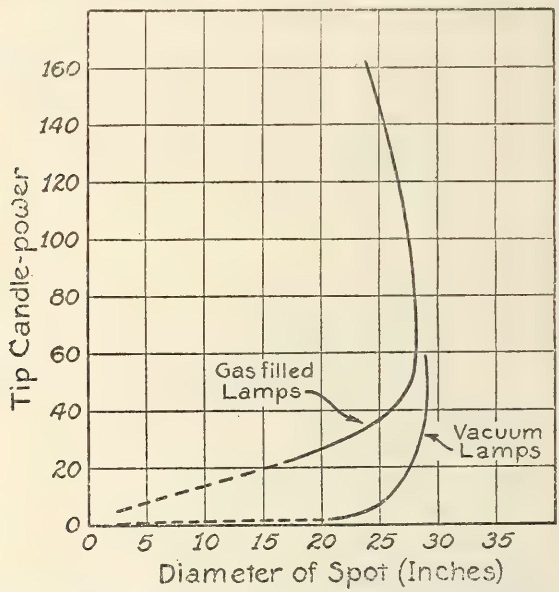


Fig. 11.—Size of spots of lights from a number of lamps of similar construction as measured by the apparatus described in Test No. 5. Readings were taken at 700 feet and the background field was comparatively dark.

as of those in the previous tests. In Fig. 11, the variation of spot size of a number of similar lamps with varying tip candle-power as measured in this way is given.

Test No. 6—

That the spot size depends also upon the brightness of other objects within the field of vision would be expected from the resultant change in the condition of the eye and this effect was observed in several experimental sign tests. Upon two particular occasions, very striking illustrations of this dependence was obtained. On the experimental sign board, four letter N's were erected. These letters were all exactly alike and quite closely spaced. They were 4 ft. high and contained 50-watt "daylight" lamps, that is, gas-filled lamps in light blue bulbs. At 1400 ft.,

when only one letter was lighted, it appeared as an almost solid mass of light; no one of its strokes could be distinguished from the others. When the two outside letters were lighted their characters became vaguely discernable. When all four letters were lighted, those two that were inside were quite distinct while the outside two were less sharp but more distinct than they had been before. In the close neighborhood of the other bright objects, the spots of light from these lamps apparently became smaller, the lines of the letters narrower, the critical dimensions greater and the legibility of the sign was increased. It has been suggested that this is due to the partial closing of the iris. To test this possibility, when only one letter was lighted, a flash lamp was held in front of the observer's eyes and moved about so that at times it was entirely out of the field of vision and at others he saw principally the flash-light and the sign was seen through a very heavy halo. There was no apparent increase in legibility.

Test No. 7—

An other sign (See Fig. 10) consisted of a letter "N" of 50-watt "day-light" lamp, 30 in. high which was surrounded by a 5-ft. circle of 50-watt gas-filled lamp. When the "N" alone was lighted, it appeared, at 1500 ft., as a single solid spot of very bright light. When the circle was flashed on, the letter "N" seemed to emerge through the spot and became clearly legible. The effect was as though the circle had dissolved the halation.

Although the fact that the apparent size of a spot of light from any light source and the width of the line of light from a row of light sources are increased with the intensity and brightness of the light sources and with the distance at which they are seen, that they are decreased in some ratio according to the contrast of their brightness and intensity with those of the proximate background and with that of the general surrounding field, that they vary with the changes in atmosphere and the color of the light, is indicated in these tests, there are yet to be determined the exact laws that govern these variations and whether any other factors enter into them.

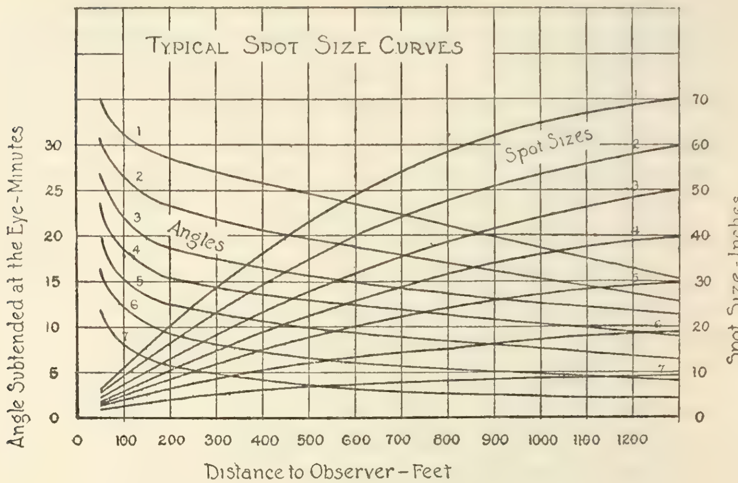


Fig. 12.—The relation between the spot diameter and the angle subtended at the eye by the spot. These curves represent values coming within and below the range of those in common practice in electric sign lighting.

A more exact conception of the variation in spot size may be obtained by translating these sizes into angles subtended at the eye. Fig. 12 gives a typical nest of curves with values of the general order obtained in the tests and which shows the relation of the size of spot, distance and angle at the eye. The curve that is marked 2 coincides roughly with the data obtained from a gas-filled lamp the tip candle-power of which is 125. To make this visual conception complete as it applies to electric signs, it is necessary to remember that the angle at the eye subtended by the top and bottom lamps of a letter decreases very much more rapidly than the angle of the spot does as the observer moves away. Thus the angle of the spot relative to the angle of the sign increases.

All of the analysis thus far given has been devoted to legibility at the limiting distance, directly in front of the sign. It is quite obvious that the limiting distance of legibility in any other direction will be less. In the early observations, it was noted that roughly a circle tangent to the front of the sign seemed to bound the area within which a sign was legible. Referring again to the critical dimension of the sign and the resolving power of

the eye, we find that an exact circle should be this limiting boundary.*

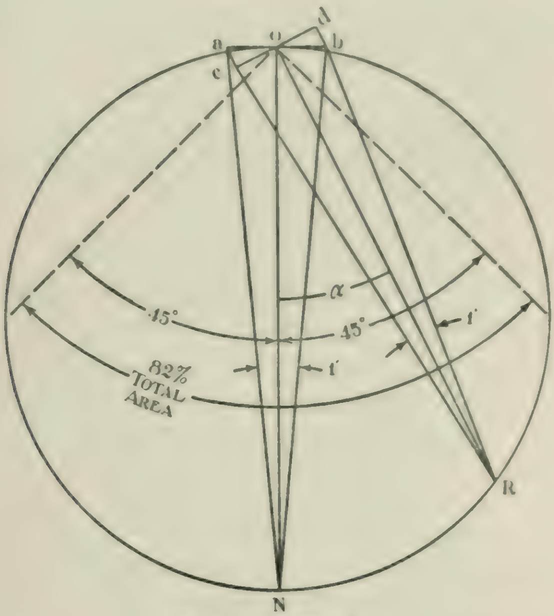


Fig. 13.—Legibility circle.

This is true for all practical cases, but it is based upon an assumption that the width of the line of light from a row of lamps remains the same when it is viewed in other than a direction normal to the sign or through the tips of the lamps; or that

* In Fig. 13 the point O represents a sign, the face of which lies in a plane perpendicular to the paper and through line a O b.

"N" represents a point on a line perpendicular to the plane of the sign and at the limit of legibility.

a b represents the critical dimension of the sign. (It is drawn large for graphical clearness).

Angle a N b is, therefore, one minute of arc.

O R is any other line through O and in the plane of the paper and angle is the angle between O N and O R.

c d is a projection of a b upon a line perpendicular to O R and through the point O.

If R is on a circle whose diameter is O N, then

and $\quad O R = O N \text{ Cos } L$

and $\quad c d = ab \text{ Cos } L$

and $\quad$ angle a N b is similar to angle c R d

and therefore angle c R d one minute of arc and R is at the limit of legibility of a sign whose critical dimension is c d. This being the same dimension as a b foreshortened, it is the critical dimension of the sign in the direction of O R and, therefore a circle bounds the area of legibility of a sign.

the candle-power is uniform at all angles. This is roughly true for all but the smaller lamps now used in signs. In as far as there is variation from equal intensity in all directions, there are slight (but by no means proportional) variations in the form of the area of legibility.

This legibility circle is the area in which the sign may be effective. Considering it as an exact circle, it is equal to

$$\frac{\pi L^2}{4} = 0.7854L^2$$

where L is the limiting distance of legibility of the sign. In the small sign shown in Fig. 2, L is actually about 1300 ft. and the area therefore about 1,320,000 sq. ft.

It has often been observed that a sign with a characteristic border or pattern will have apparently a circle of legibility very much greater than that which might be predicted from the critical dimension of the wording. Much of this is of course due to the characteristic pattern which is recognized long before the lettering can be read, but some of it is due, as was seen in test No. 7 to the effect of the border in removing the severe contrast of the bright lamps in the letter and the black surrounding field, so that the lettering itself is legible, to a person unfamiliar with the characteristic border, at greater distances than it would be were there no border.

The limiting distance is not the only characteristic of legibility that must be considered. It is usually desirable that the sign be easily legible over a considerable range of intermediate distances. It requires so much effort to read many signs while they are still very close, that their effectiveness is very seriously reduced. In order to distinguish between the legibility which is limited by the distance and the visual acuity of the observer, and legibility which, well within the maximum distance, is limited because of the peculiar construction of the sign or the selection of the light sources, this phase is called the ease of reading, in contra-distinction to legibility as it has been used above.

There are two principal factors that affect the ease of reading a sign without altering the limit of its legibility. They are the finish of the bulb and the construction of the metal letter which carries the lamps. Diffusing light sources are used principally

in small, low hanging signs, with two objects in view; the first is to reduce glare and the second is to produce a smoother finish, which tends to make legibility easier. This is true especially in narrow trough letter signs. If the lamp is clear, at the shorter distances its spot of light is not much larger than the filament size.

The part of the letter structure in which the lamp sockets are set is called the letter face. The walls about the lamps are called the trough sides. The letter face and trough sides are illuminated by the lamps; but even with the best reflecting paint their brightness is comparatively low in contrast with that of the light sources. The area of the face and trough sides is great and when the light source spots are small, and very bright, the effect is very uneven and spotted. When the lamp has a diffusing bulb, the spot is never smaller than the bulb size, the intensity is very greatly reduced, the ratio of dimly lighted letter area to the less intense spots is reduced and the effect is that of an increased smoothness and an increased ease of reading.

The maximum distance at which diffusing light sources cease to aid in ease of reading is that distance at which, under the conditions in question, a clear glass lamp will have a spot of light apparently equal in size to the diameter of the bulb. At greater distances than this, the only difference in the appearance of a clear glass and a diffusing bulb lamp is that the latter has less sparkle or "life;" it is slightly duller.

The last factor affecting legibility which is discussed here, is the construction of the letter face and trough sides. The finish or construction of neither the trough sides nor the letter face adds to the limit of legibility of a sign. When clean and white both have the effect of making legibility easier for small signs at short distances. This is due to the filling up of the spaces between the spots of light with a white line not as light as the spot but considerably whiter and brighter than the background. Their chief advantage is that of producing a smoother and more continuous line, a sharper cut off between the letter and the background.

In the ordinary construction of larger signs, the trough sides have little or no effect on the legibility of the letter. At all ordi-

nary distances, the width of the line of light from the spots is greater than the width of the visible line of reflected light on the letter face. Except at angles from the normal so great that the light sources are hidden, the trough sides are quite invisible.

The distance at which this is true depends, of course, upon the brightness and intensity of the light sources, their spacing, their light distribution and the whiteness of the letter face. For any given size of lamp and spacing, in any degree of surrounding illumination, the line of light will have a definite width when seen at a given distance. If the light distribution is such as to throw a large part of the light back into the trough, the line of reflected light on the trough will be wider and whiter and the distance at which its effect will be visible through the line of light from the sources will be greater. If the distribution of light is such that a smaller part is thrown back into the trough and more out through the tip, the distance will be less because the width of the line of spots is greater and the reflected light line narrower.

In small signs, seen at distances less than, say, 300 ft., the trough sides prevent the light from the lamps in the sign from illuminating the box or frame work on which the letters are mounted and in this way they make a sharper contrast between the sign letters and the surrounding background. At these short distances, where the width of the line of light is not a factor and the only question is one of ease of reading, a sharp contrast aids in legibility.

When smaller signs are made without a trough, it is necessary to space the lamps much more closely. This method of construction possesses certain advantages over the trough letter construction, with more widely spaced light sources. The sign collects less dirt and so maintains its continuity of line and legibility much longer. When a troughed letter sign with only three lamps in the vertical stroke becomes dirty, so that the spaces between the spots no longer are materially whiter or brighter than the illuminating of the surrounding objects, (it is remarkable how quickly this condition occurs in some cities) the sign has the appearance of a more closely lamped sign with all but three of the lamps burned out. Such signs are distinctly unattractive and often scarcely legible at any distance.

The chief effect of a white letter face at the greater distances, is in an added intensity rather than a greater smoothness.

This does not mean that there is no advantage in the trough construction; there is a very great advantage. But too often, the trough is relied upon to supply too much of the light of the letter. It does not do this. Any small sign built without troughs would have an improved appearance at the shorter distances if troughs were added, the lines would be more solid and reading at an angle would be rendered more easy providing the trough is clean and white. When the lamp spacing in a troughed letter sign is more than 25 per cent greater than it is in a troughless raised letter sign, the appearance is less satisfactory.

The attracting power of an electric sign presents quite a different problem to the designer. Such factors as location, competitive signs and attractions, average speed with which people pass, and the very nature of the people themselves enter into the analysis. All of these variables are important but they are somewhat beyond the scope of the present paper. Of the factors we have discussed, the pattern, its size and shape, is important and the brightness, intensity, color and finish of the light sources also play their part; attention is directed here especially to the effect of these upon the attracting and selling powers.

For the maximum of legibility it was found that a very low order of brightness and intensity of light source is required. On the other hand the attracting and selling power of a sign increases with the brightness and intensity of the sources, and therefore to have great attracting power a higher order of these is demanded. It is necessary to strike a balance between legibility and attracting power. The attracting and selling powers of a sign are of great importance in any case; usually they are valued more highly than is legibility. For many signs so located that legibility at great distances if of no value (either they are hidden by buildings or there are no people beyond a limited distance to read the sign) the legibility circle may be relatively small, making it possible to have a considerably greater attracting and selling power. It is this fact that has lead recent practice to adopt larger light units, especially the blue bulb and "daylight" lamps, whose whiter light gives an unique sign of great attraction.

As commonly used in exposed lamp electric signs, that is, when viewed through the tips, the apparent color of the lamps (without color caps) as they progress toward the brighter and whiter light is as follows:

1st. Vacuum lamps with straight filaments 2.5, 5 and 10 watts.

2nd. Vacuum lamps with coiled filaments 25 and 50 watts.

3rd. Gas-filled lamps 50, 75, 100 watts and greater.

4th. Vacuum lamps with light blue bulbs 25 and 50 watts.

5th. "Daylight" lamps 50, 75, 100 watts and greater.

Although the spectral character of light from lamps of the first and second groups is substantially the same, the apparent difference in color is materially greater than that between lamps of equal wattage in the second and third groups or in the fourth and fifth groups. This apparent difference in color no doubt results from the factor of difference in brightness and intensity of light sources.

When viewing at a short distance two signs in which one has lamps from group two and the other from group three or from groups four and five, but of the same wattage, the chief difference between them is that a certain luster and sparkle or "life" seen in the gas-filled lamp sign is lacking in the other. At all except the greater distances, or where the signs are very widely separated, a small difference in color is also visible. If the signs are farther away, this difference becomes less noticeable.

To make some sort of definition for this difference, two groups of lamps were set up and observed at various distances. Each group contained 20 lamps, spaced on 11-in. centers in two rows of ten each and the groups were set 70 ft. apart. At the greater distances they appeared as single spots and as such, the difference could be detected in the size of the spot, when it

could not be seen in the color. Such differences were overlooked. To classify the color differences, five standards were assumed as follows:

A. Meaning no observable difference.

B. Meaning a difference so slight that after looking at the two spots a moment no difference could be detected but by resting the eyes a moment, the difference was again seen.

C. Meaning a difference at all times noticeable but so slight that if only one had been lighted and it was known to be one of the two, it would have been difficult for anyone except an expert to tell which was lighted.

D. Meaning difference, clear and distinct, but not enough to have any value in advertising, as for example (if it could be done) the use of both lamps in the same sign to illustrate different things.

E. Meaning difference very great. Great enough to have contrast value.

Observations were made at three points. At the first point, 700 ft. from the sign, all of the differences came in classes C, D and E. At the second point which was three quarters of a mile away, the differences were somewhat less, as follows:

		Vacuum lamps.					Gas-filled lamps.				
		10-watt clear	25-watt clear	25-watt blue	50-watt clear	50-watt blue	50-watt clear	50-watt blue	75-watt clear	75-watt blue	100 watt clear
Vacuum	25-watt clear	D	—								
	25-watt blue	D	C	—							
	50-watt clear	E	B	C	—						
	50-watt blue	E	C	B	C	—					
Gas-filled	50-watt clear	E	B	D	B	C	—				
	50-watt blue	E	D	C	D	B	C	—			
	75-watt clear	E	D	D	C	D	B	D	—		
	75-watt blue	E	D	D	D	C	C	B	C	—	
	100-watt clear	E	D	D	D	D	D	C	A	C	—
	100-watt blue	E	D	D	D	D	D	D	C	A	C

At one and one quarter miles, the difference became still less marked as follows:

		Vacuum lamps.					Gas-filled lamps.				
		10-watt clear	25-watt clear	25-watt blue	50-watt clear	50-watt blue	50-watt clear	50-watt blue	75-watt clear	75-watt blue	100-watt clear
Vacuum	25-watt clear	C	—								
	25-watt blue	D	B	—							
	50-watt-clear	E	A	B	—						
	50-watt blue	E	B	A	B	—					
Gas-filled	50-watt clear	E	A	B	A	B	—				
	50-watt blue	E	B	B	B	A	B	—			
	75-watt clear	E	D	C	B	B	A	B	—		
	75-watt blue	E	D	D	C	B	B	A	B	—	
	100-watt clear	E	D	D	C	C	B	B	A	B	—
	100-watt blue	E	E	D	D	C	C	B	B	A	B

As the distance to the observer is increased, the differences in color are diminished. From other tests, however, it is known that the color differences become more apparent as the size of the sign and the number of the lamps are increased. At three quarters of a mile, in a sign containing 300 lamps when equipped alternatively with 50-watt vacuum light blue glass and 50-watt "daylight" lamps, the difference was of the D class instead of the B class as shown in the table for the 20 lamps.

APPLICATIONS

There are a number of practical applications, mention of a few of which will tend to summarize the principles discussed in this paper.

No. 1—The most direct application is found, of course, in the spot size data. For example, a 100-watt lamp has an apparent spot size of, say, 90 in. when viewed at a distance of three quarters of a mile. This size will be reduced (the factor is not yet determined) in some relation to the number of lamps in the sign, the area of the sign, the relative brightness of the surroundings and background, etc.; it may, for example, be 60 in. under the specific conditions. If a sign is to be designed then, for reading at that distance and 100-watt lamps are to be used, it is obvious that the designer must make up the pattern on the assumption that the finest line that will be distinguishable will be 60 in. wide.

No. 2—In the test which was conducted to determine the effect of other letters upon the legibility of any one letter, it was found that larger lamps could be used and maintain the same legibility, when the sign was large. In this way the attracting and selling power of that sign might have been increased. If the sign had been smaller, which is the equivalent to saying that had there been two letters N instead of four, smaller lamps would have been needed, lest the legibility were seriously reduced.

No. 3—Or again, a different application of the same fact and one which the letter N in the circle sign of Fig. 10 illustrates, it might be found of some sign which was so small that when brighter lamps were installed to increase the attractive power the legibility was greatly reduced, that a border of bright lamps might restore the range of legibility.

No. 4—Many applications of the increased range of legibility with decreasing brightness can be found. One of these was actually tried and found to be highly successful. A sign was built, in which the lamp spacing was made purposely small. The letter spacing was also small and the letters were of the solid massed type. High wattage "Daylight" lamps were used. The result was a tremendous blaze of light. It was very strongly attention compelling, but as was expected, its range of legibility was comparatively short, far below, perhaps not a quarter of what a simple single line letter sign, equipped with 10-watt lamps would give. In cycles of about 10 seconds, this sign was dimmed, by means of rheostats until it was black and then brought up again to its full brilliancy. The effect was remarkable. When seen at distances very nearly up to the theoretical maximum for the center line critical dimension of the sign, it appeared like a search light sweeping the ground. The observer looked and saw nothing but a huge spot of intensely bright incandescence. But as he stood looking at it, it grew dimmer, less white and, depending upon where he was, at some time in the cycle, the lettering began to take shape, to come first dimly and then strongly through until at last it stood out sharp and clear and distinctly legible and then slowly disappeared like the finest of red ink lines on a very black sky. Such a sign has the maximum of attractive power so far as bright light sources can attain this, and at the same time the greatest circle of legibility or effectiveness and has too an unique and fascinating appearance of slow movement and rhythm.

DISCUSSION

A. H. Ford: I have been much interested in this paper, because the author draws the same conclusions from his large scale experiments that I drew, in a paper presented to the society in 1914, from some small scale experiments. While he has made the apparent size of the lamp his basis for calculation I made the visual acuity for bright lines on a dark background the basis for calculation. When using the visual acuity figure as given in the text books (one minute of arc) one must remember that this figure is for black lines on a white background. It will therefore not apply to signs composed of incandescent lamps.

I would suggest eye fatigue is the cause of the seventy five watt lamp giving the larger apparent spot size than the one hundred watt lamp.

Louis Bell: This paper is interesting from the standpoint of physiological optics. It is strictly a matter within the field of physiological optics rather than illumination, as such. The thing I wish to call attention to particularly is the vast difference in visibility between a line whether or not made up of units which are inside the limit of visual acuity, and the ordinary data which are given for the visibility of separate objects.

I happen to have tried, about a year ago, a lot of experiments on visibility of bright lines with the somewhat astonishing result, that you can see a bright line against a black background down to a fineness which is enormously less than the ordinarily assumed value would be.

A bright line, on a dark background is visible down to, at a pinch, below one second of arc if the brightness is considerable. You can catch a glimpse from a bright wire stretched on a dark field down well below one second of arc in width, and allowing a large factor of safety there, you can make a line perfectly visible down very far below one minute of arc.

On the other hand, as has just been pointed out, the separation that you can distinguish is quite another matter. To see two points as separate you need a good deal more than the distance required to distinguish a line, and I think very much of the trouble in electric signs has come from failure to recognize that fact, and using too bright lamps with the idea that they become more visible as they are brighter instead of which they often are very much less visible. The difference is astoundingly great, and of course as the previous speaker remarked, there is a unit of separation due to the size of cones in the eye beyond which you can't go, and furthermore, as you go further and further away from the lamp, the image gets smaller and smaller, and you don't have very much effect on the visibility after you reach a certain point, but the difference between distinguishing two separate objects and appreciating the width of an illuminated line is astoundingly great and ought to be taken into account.

A. H. TAYLOR: Irradiation is undoubtedly the true explanation of many of the observed phenomena, for example the greater legibility of the letter N when surrounded by a circle of lamps than when seen alone.

I would like to ask whether the author has yet made a similar investigation of colored light, to determine whether certain colors may be more easily resolved than others under similar conditions.

C. A. ATHERTON: I am very much interested in the suggestion Prof. Ford makes that it was eye fatigue which made the size of spot from the largest light source appear to be smaller than the spots from light sources of intermediate sizes. We also felt that this might be caused by eye fatigue in some of our earlier tests and took great pains to determine whether this was so. The procedure at first was indentical night after night in that we worked with the less intense light sources early in the evening and with the more intense light sources later. When we consistently found that a smaller spot was obtained with the largest lamps, we tried reversing the procedure, working with the larger ones early in the evening and the smaller ones later, but without appreciably affecting the relative sizes of spots obtained. We also tried to eliminate eye fatigue by having two observers alternate, the one closing and resting his eyes while the other made readings. Then for comparative purposes we had a single observer make readings consecutively all of the evening. These readings were taken at the rate of about three a second and in series of 12 to 18, after which a new light source was substituted. In all of this work we were unable to find any effect of eye fatigue other than that the divergence of readings always increased as the evening became late.

I am very sorry to have to reply to Mr. Taylor's question negatively. We have not as yet worked with color light sources at all.

COLOR TEMPERATURE AND BRIGHTNESS OF VARIOUS ILLUMINANTS*

BY EDWARD P. HYDE, AND W. E. FORSYTHE**

Quality of Light—The quality of light has become an important factor in illumination design. Physicists have long been interested in the distribution of energy emitted by radiant sources, but it has only been within the last ten years that the quality of light has been accorded an important place in illumination design, and that methods of evaluating it have been developed.

In 1908 Woodwell and one of the present authors[1] conducted a series of tests on a Moore tube installation in the New York City post office which included a study of the color of the light. Shortly before this time[2] F. E. Ives had invented a colorimeter for testing the color of papers, fabrics and other reflecting media, and it occurred to one of the authors that this instrument might be employed to determine the color of the Moore light as installed. In order to obtain as trustworthy results as possible F. E. Ives was requested to make the color tests with his own instrument, probably the first test of the kind that had ever been made. Unfortunately the conditions of the tests were not satisfactory and the original results were subject to some modification in consequence of a subsequent series of tests by H. E. Ives,[3] at that time a member of the staff of the Nela Research Laboratory.

There followed rapidly the investigation of the quality of light of various illuminants by H. E. Ives and others, employing the colorimeter as the measuring instrument. Subsequently a different type of colorimeter was developed by Nutting,[4] and the application of color measurements gradually became general.

* A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26–29, 1921.

**Nela Research Laboratories, National Lamp Works of G. E. Co., Cleveland, O.

[1]Hyde & Woodwell, Trans. I. E. S. **4**, 871, 1909.

[2]*Journal Franklin Inst.* **164**, 47, 1907.

[3]Trans. I. E. S. **3**, 627, 1908.

[4]*Bulletin* B. of Stds. **9**, 1, 1913.

The quality of light as evaluated by means of a colorimeter is expressed in terms of the per cent of red, green and blue light as compared with some accepted daylight standard. This measurement gives valuable information, but to the uninitiated the interpretation of the results is difficult, indeed in some regards more difficult than the interpretation of a spectrophotometric curve of the source, and even to the few who are reasonably familiar with such measurements the complex methods of stating the results is not entirely satisfactory. However, were most of the common light sources so distinctly selective in their radiation as the Moore nitrogen tube, the colorimeter method would still, quite probably, be the best method available for determining the color of the integral light, though supporting evidence from a determination of the spectro-photometric curve would be necessary for the complete interpretation of the results. But the fortunate circumstance that the great majority of illuminants in common use radiate nearly, if not quite like a black body, with respect to the distribution of energy in the spectrum, makes possible the use of another, and in many respects much more satisfactory, method of measuring and expressing the quality of light of illuminants. A brief discussion of this method, and a summary of results obtained with it, constitute the subject matter of this paper.

The method employed in determining *color temperature* has been described in such detail in various papers[5] from the Nela Research Laboratory that only a very brief summary need be included here. It rests on the fact that the quality of light emitted by a black body is a unique function of its temperature. As the temperature is raised the emitted light passes from a reddish color to more nearly white, until at the temperature of approximately 5600° K. it matches sunlight in color. Therefore, for any illuminant which emits energy in the visible spectrum so distributed that it corresponds to that of a black body at some temperature, it is possible to determine this temperature of approximately equal energy distribution, or *color match,* which temperature so determined is the color temperature of the source.

[5]*Astro. Phys. Journal* **36**, 89, 1912.

The procedure of this determination is simple and readily applied in any photometric laboratory, if a standard electric incandescent lamp with known color temperature scale is available. It consists in placing the test lamp on one side of a photometer (using preferably the Lummer-Brodhun contrast photometer, because of its color sensibility) and adjusting the voltage of an electric comparison lamp situated at the other end of the photometer bar until the two fields as seen in the photometer are of the same color. This setting is made most accurately if, when the voltage is changed, the photometer is moved so that a photometric balance is maintained. The test lamp is then replaced by the standard lamp with known voltage-color temperature scale and the voltage of the standard lamp is adjusted until there is again a color match with the comparison lamp maintained at the voltage determined in the first part of the experiment. From the calibration curve of the standard lamp the color temperature corresponding to the observed voltage may be read, which is the color temperature of the test lamp.

The calibration of the standard lamp must ultimately be obtained through comparison with a black body, but this has already been done[6] for both tungsten and carbon lamps and the results published in form convenient for use.

By the determination of color temperature a number is given to express the quality of light of those sources to which the method, as presented thus far, applies. A comparison of the color temperatures of some of the common illuminants will illustrate the simplicity and significance of this method. Thus the color temperature of the ordinary sperm candle is 1930° K., that of the 4-watt-per-candle carbon lamp 2080° K., that of the 1.25 w. p. c. vacuum tungsten lamp 2400° K., that of the 500-watt, 0.72 watt-per-spherical-candle tungsten lamp 2880° K., and that of the sun as observed at the earth's surface 5000° K. With a few such fixed points in mind one may readily place any illuminant in regard to the quality of its light if its color temperature is given. The above illustration shows how large the gap is between the color of the light of even the most efficient tungsten lamp and that of sunlight, as compared with the much smaller

[6] *Phys. Rev. N. S.* **10**, 395, 1917.

differences between the various common illuminants of the present and the near past.

The method of obtaining color temperatures as outlined above is restricted to those illuminants which may be color-matched with a black body at some temperature. It does not apply to illuminants so selective in their radiation that a color match with a black body may not even be approximated, nor to those illuminants operating at temperatures higher than those available in black-body electric furnaces. The color temperatures of the latter class may theoretically be determined in any one of three ways:

1. From spectrophotometric comparison with a black body, or with a color-standardized lamp, and computation of color temperature from known black body radiation laws;

2. From pyrometric determination of the relative brightness in two wave-lengths near the ends of the spectrum;

3. From the use of a suitably calibrated blue screen, or other suitable screen,[7] in conjunction with the black body or color-standardized lamp.

These means of determining the color temperature of high temperature sources of the black body type might appear, at first sight, so complicated as to vitiate the entire scheme of using color temperature as an index of the quality of light, but a little consideration will show that they constitute no real restriction on the use or value of the method. For all ordinary sources of the black body type the color-standardized tungsten lamp is quite sufficient to make determinations of color temperature and for any new sources of higher color temperature which may be developed the scale may readily be extended. These then in turn may be employed as standards to give the higher points on the scale. For such extremely high color temperatures as those of the sun the ordinary experimenter has no occasion to make color temperature measurements. He desires to know merely where they come on the scale, and their color temperatures may be determined once for all in a physical laboratory using some

[7] *Priest Journal Optical Soc.* **5**, 178, 1921.

one of the more complicated methods. The color temperature of the sun given in this paper was determined by means of calculations using Abbot's[8] data.

The principal difficulty in the universal application of the method of color temperatures is to be found in connection with illuminants which are not of the black body class, but which rather radiate so selectively that a color match with a black body may not even be approximated. Fortunately the number of these illuminants is not great, and the very fact that they do not lie on the black body scale of color temperature is sufficient reason to accord them special treatment in each case. There are, of course, varying degrees of selectivity to be found in the different kinds of such illuminants, from the incandescent gas mantle which exhibits a continuous spectrum with only relatively slight departure from the spectral energy distribution of a black body to the mercury vapor arc which emits all its energy (in the visible spectrum) in a few very narrow spectral bands, and which has an integral color quite different from that of a black body at any temperature.

For such sources as the mercury vapor arc the only information of significant value must be obtained from a study of the spectro-photometric curve of the source, for whatever its integral color may be the distortion of the color of objects illuminated depends entirely on the location, number and intensity of the bright lines in its spectrum. It is for the other class of selectively radiating illuminants such as the gas mantle, which exhibit a continuous spectrum though somewhat distorted with respect to a black body, that a modification of the method of color temperature is desired in order to locate them on the same scale, by determining in some way, if possible, how to express their divergence.

A method of doing this has suggested itself to the authors, but further experimentation is necessary before its practicability may be determined. This suggested method consists in determining the necessary amount of red or green or blue, or of any two of these which when added to the integral illumination from a lamp of some properly determined color temperature will pro-

[8] *Annals Astrophysical Observatory* **3**, 1-7.

duce an illumination of the same color as that given by the source under investigation. If, for example, the quality of light from the ordinary gas mantle, which is slightly greenish in color, could be expressed as having a color temperature of x° K. + y per cent of a standard green light, a unique evaluation of the quality of the light from the mantle would be secured, and at the same time its divergence from the black body scale would be given.

The authors have not yet had an opportunity to test fully the practicability of this method, though the work done gives promise of some success. But whether or not such selectively radiating illuminants as the gas mantle may be brought onto the same scale as that which is used for illuminants lying on the black body scale, the value of the latter for the great number of cases to which it is applicable is in no way vitiated.

Brightness.—Making use of the color temperature and the brightness temperature the brightness of the different radiators may be calculated. The distribution of energy in the visible spectrum of a source whose color temperature is T_c is given by Wien's equation

$$E_\lambda = K_T c_1 \lambda^{-5} e^{\frac{-c_2}{\lambda T_c}}$$

where the added factor K_T corresponds in some respects to an emissive power. For the substances investigated, K_T is less than unity, that is, when the source investigated is color matched with the black body it is less bright than the black body. From the equation it can be seen that the ratio of brightness for any wave-length interval or for the total radiant flux for the black body at temperature T and the source being investigated at color temperature T_c is given by $1/K_T$

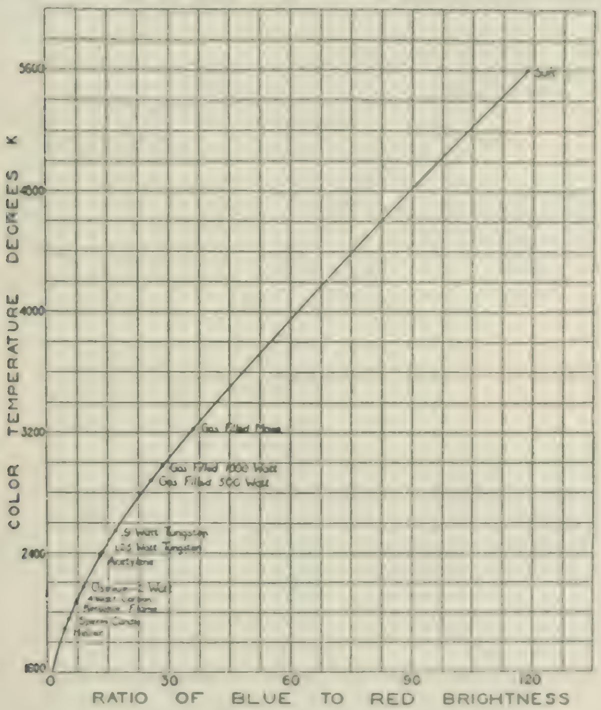
The value of K_T can be found from the color temperature and the brightness temperature as follows:

$$\log K_T = \frac{c_2 \log e}{\lambda} \left\{ \frac{1}{T_c} - \frac{1}{S} \right\}$$

Using the value of K_T thus obtained and the known values of the brightness of the black body at temperature T_c the bright-

nesses of the different sources were computed and are given in Table 1.

Results.—In Table 1 are given the color temperatures of a number of illuminants lying on or very nearly on, the black body scale of color. Several of these illuminants have been arranged



Plot of Color Temperature of Various Illuminants

on a plot, the ordinates of which are black body color temperatures, and the abscissae, for want of a better scale, are plotted as relative ratios of the blue ($\lambda = 0.465$) to the red ($\lambda = 0.665$). The wave-lengths chosen are those corresponding to the blue and red glass screens respectively used with the optical pyrometer in determining the color temperatures of sources of very high color temperature such as the sun as described in a previous paragraph. This curve shows the increase in color temperature with the increase in efficiency of the various light sources. It also shows the wide gulf between the most efficient incandescent lamp and the sun.

The table of color values given is not intended to be complete but contains only the data which the authors already had available. It is expected that data on several additional sources which fit the black body scale will be added to the table in the near future. It is also planned to investigate some of the sources that do not lie on the black body as seen by the method outlined above.

TABLE I. COLOR TEMPERATURE, BRIGHTNESS TEMPERATURE, AND BRIGHTNESS OF VARIOUS ILLUMINANTS.

Source	T_c	S (λ=.665)	Brightness c/cm²
Gas flame[1]			
Batswing	2160		
Candle shape about 10 cms. high	1875		
Hefner as a whole	1880		
Candle			
Sperm	1930		
Paraffin	1925		
Pentane[2]			
10-cp. std.	1920		
Kerosene			
Flat wick	2055	1500	1.27
Round wick	1920	1530	1.51
4 w. p. c. carbon	2080	2030	54.9
3.1 w. p. c. treated carbon	2165	2065	70.6
2.5 w. p. c. gem	2195	2130	78.1
2 w. p. c. osmium	2185	2035	60.8
2 w. p. c. tantalum	2260	2000	53.1
Acetylene as a whole[3]	2380		
One spot[3]	2465	1660	6.69
Mees burner	2360	1730	10.8
1.25 w. p. c. tungsten	2400	2150	125.0
2.3 w. p. c. Nernst	2400	2320	258.0
Sun[4]			
Outside atmosphere	6500		224000
At earth's surface	5600		165000

[1]Coal and water-gas mixture, approximately 600 B t. u.
[2]Color matched by Bureau of Standards.
[3]Burner (no reflector) from auto headlight "prest-o-lite."
[4]Calculated from Abbot's data.

TABLE II. COLOR TEMPERATURE AND EFFICIENCY OF VARIOUS TYPES OF TUNGSTEN LAMPS.

Lamp	Specific out-put Lumens per watt	Color temperature
40-watt Type B (vacuum)	10.0	2500
100-watt Type C (gas-filled)	12.6	2740
500-watt Type C (gas-filled)	17.4	2880
1000-watt Type C (gas-filled)	20.3	2985
1000-watt stereopticon	24.2	3175
900-watt movie	27.3	3220

These temperatures are based upon the assumption of Wien's equation with c_2 taken as 14350 μ degrees and upon the melting point of gold taken as 1336° K. On this scale the melting point of palladium has been found to be 1828° K. For convenience in the calibration of optical pyrometers, a black body held at the melting point of palladium is used as the point of reference.

DISCUSSION

E. L. NICHOLS: Mr. Chairman, Gentlemen, this paper has interested me very much because, as some of you know perhaps, I was delving in this direction, more or less blindly a quarter of a century ago, making various attempts to obtain some sort of a relationship between color and temperature at a time when such things were not yet standardized.

We did not know even approximately the temperatures of lamp filaments.

At present the relationship is sufficiently definite for all those light sources with which Dr. Hyde proposes to deal; leaving out of account vacuum tubes and the like. It is a very useful suggestion and it occurs to me that it might even be possible to educate the public to a perception of the color corresponding to temperatures by the use of some scheme of graded tints running from a dull red to the full white corresponding to sunlight, with the temperatures indicated along side. It would be something like the color scales used in tempering iron before the days of the optical pyrometer. A projection scheme would be still more effective since one can get screens to produce with some exactness the colors of our various illuminants so that they could be brought into comparison with the light obtained by using a good daylight filter. Thus the black body temperature of candle light or of the Welsbach burner or of the acetylene flame would soon become a *number* designating its color and this would soon suggest the corresponding color sensation to the mind even of lay men. I think that at present even the illuminating engineer needs to have his color sense trained so that temperature will convey to him a color concept.

H. P. GAGE: We had some interesting experience in getting color screens to do very much what Professor Nichols has indicated for changing the effect of one color-temperature to another color-temperature. For example, if in front of an electric lamp we put a yellow glass of the right spectral composition it would reduce the intensity of the lamps to, we will say, that of a red-hot wire. Not only will there be a reduction in intensity but the color will be shifted towards the redder hue of the lower temperature wire. Such a yellow absorbing screen has not been worked out fully in glasses but in the red part of the spectrum a pair of glasses has been developed which reduce both the intensity and the color of a black body radiator in the correct ratio.

I could, by taking sufficient time, draw a curve depending upon the well-known Wien equation which when plotted as reciprocal wave lengths against the logarithm of the transmission would be a straight line passing through the zero. This curve represents the spectral distribution of a yellow glass which would serve the purpose here stated.

On the other hand, I can place in front of a lamp, a piece of blue glass which will increase the color-temperature of the source although it reduces the intensity; that is, we get a bluer light. Thus with a tungsten lamp it is possible to obtain an illumination the same color as sunlight or daylight. To change from some definite temperature as that of a gas-filled lamp 2,700° Kelvin to some other definite temperature as, say, 7,000° Kelvin, we can draw a curve showing the relation between the transmission for each wave-length, with respect to the transmission for another given wave-length such as 0.41 μ. A study of the Wien equation reveals an interesting set of relationships. If a glass will change the color-temperature of a black body radiator at a certain temperature, T_1, to that of a second temperature, T_2, it will also change the temperature of a body at a third temperature, T_3, to that of a fourth temperature, T_4, when the relation between these temperatures is

$$\left\{\frac{1}{T_1}-\frac{1}{T_2}\right\}=\left\{\frac{1}{T_3}-\frac{1}{T_4}\right\}$$

If we take a thinner section of the same glass we can change the color-temperature of the transmitted light according to the thickness used. With glasses as here described it should be practical to make a color-temperature pyrometer which will increase or diminish the color-temperature of a standard lamp to that of the color-temperature to be measured. In the yellow we have not as yet succeeded in getting quite the right spectral transmission but we have developed, and there is at present available, a supply of blue glass which satisfies the relationships given above for increasing the color-temperature of light sources.

C. F. Scott: I have been impressed, as I am sure others have, by the beautiful simplicity of the presentation which Dr. Hyde has made, the way these difficult and intricate and involved matters are simplified and put in the form of a curve, and the magnificent way in which the different experimental data line themselves up to the curve. The fact that this is work that Dr. Hyde has been engaged in for many years and that the later results line up with the former ones is also a gratifying matter.

If I may speak of another thing a moment; I come to these Conventions to learn many things. I was impressed with the matter of eye strain and so on in the presentation this morning. I believe in exhibits and demonstrations. For myself, I think I have been fully convinced of what I thought I knew before, that illumination on the back of the head of the speaker does not aid the audience materially and that a very bright and glaring light in the field of vision is a very distracting and annoying matter to all who have to look at it.

G. G. Cousins: I would like to ask a question regarding a photometric feature. In making color matches with the Lummer-Brodhun photometer, is it desirable to work with a high intensity or a relatively low one?

J. B. Taylor: I want to ask if this term "color temperature" has been well considered, and is it properly written? Should it be a compound word? Somebody picked up this program and said, "Haven't they left out a comma? Shouldn't it be "Color, Temperature and Brightness, etc.?"

I haven't considered this enough to say, but should not that be tied together with a hyphen?

E. P. HYDE: Referring to the first question, the illumination that we use is determined upon the meter candle. With respect to the suggestion of Mr. Taylor, I can only reply that the term "color temperature" has received the most careful and scrutinizing attention in every regard except with respect to the hyphen, and I think that we ought to make that the order of the day for the next consideration and decide to put it in.

Perhaps it would not be amiss to explain a little about the origin of the term, a subject which I did not discuss in the paper because I did not expect the question to be raised. It has been the practice for many years in determining the temperature of furnaces particularly those used for melting metals and glass, where the temperatures could not be measured by ordinary thermometers, to use what has been called the "red-" or "green-" or "blue-black body" temperature. This is the temperature of an ideal radiator or black body at which it has the same emission intensity in some wave-length usually in the red. This afforded a convenient number to express the temperature of the furnace. When we came to match the integral color of a hot body such as an incandescent filament with the integral color of a black body we again had a temperature of the black body but one which was different from that at which the filament and the black body would have the same emissivity in the one wave length. In order to distinguish between these two black body temperatures a terminology was adopted and proposed some years ago in a paper before the Physical Society* in which the previously designated red black body temperature was called the "black body brightness" temperature or more briefly the "brightness temperature" giving the wave-length where necessary, while the other was called the "black body color temperature" or briefly the "color temperature" where there was no question of confusion. I think it would be well to insert the hyphen since it is a specifically defined term to mean a definite thing. I can well understand how the title of the paper may have lead to some confusion.

*Color Temperature Scales for Tungsten and Carbon—*Phys. Rev.*, 10, Oct., 1917.

EYE FATIGUE IN INDUSTRY*

BY MAX POSER.**

To study the cause of eye fatigue many factors have to be considered, particularly those pertaining to the nervous system of the human eye. For the illuminating engineer the effect of light upon the human eye is of greatest importance and the science of physiological optics has furnished us with a number of theories as to the stimulus of light upon our visual organs. We have learned to distinguish between good and bad illumination but we have a good deal more to learn as to what is correct illumination in order to cause the least eye strain.

Daylight, being a diffused light to which our visual organ is most adapted particularly when the sky is covered with light white clouds, causes the least eye fatigue as many experiments have shown. From this we conclude that diffused daylight is the best illumination, and industrial plants equipped with good daylight illumination will experience little trouble with their workers regarding eye fatigue. In the long winter nights, however, the effect of a diffused daylight is not easily produced by means of artificial light sources. Since we have no other means at our disposal, let us discuss the effect of artificial illumination on our visual organs. To understand the problem more easily, there will be discussed briefly the function of the human eye when exposed to light, and its anatomy in general.

The projecting transparent portion of the external coat of the human eye is called the cornea, which is joined to the white part of the eyeball called the sclerotic. Looking directly through the cornea from the front one can see the iris and black pupil behind it. If the relative position of the cells composing the cornea be altered by pressure from within or without, it becomes translucent and cloudy which also may happen through injury or inflammation of this structure. Powerful ultra violet light or excessive heat may impair the transparency of the cornea, and no matter if every other part of the eye be normal, with an impaired

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**Max Poser, Ph. O. D., M. R. I., F. R. M. S., Bausch & Lomb Optical Co., Rochester, N. Y.

cornea perfect vision is impossible. The cornea is composed of five layers:

1—Epithelium.

2—Membrane of bowman, a dense membrane which maintains the shape of the cornea.

3—The proper substance of the cornea, not as dense as the preceeding, but forming the greater part of the thickness of the cornea.

4—Posteria limiting layer, or membrane of descemet.

5—Endothelium.

The cornea is freely supplied with nerves.

The next, or middle coat of the eye is called the choroid, which forms a lining for the inner surface of the sclerotic. The choroid seems to consist principally of a network of blood-vessels, lined with a layer of flat, dark brown or black pigment cells. The blood-vessels supply nutriment to the various parts of the eye, while the function of the dark surface is to absorb the excess light which would otherwise dazzle and prevent accurate vision.

The choroid, like the sclerotic, is pierced behind by the optic nerve. As it approaches the front part of the eye, it folds upon itself and forms a series of folds or plaitings, which are known as the ciliary processes, which are arranged in a circle behind the iris and around the margin of the crystalline lens, and they gradually merge into what is known as the ciliary muscle, or the muscle of accomodation.

The ciliary body is composed of two parts:

1. The vascular part, supplying nourishment to the vitreous and crystalline lens, and for the secretion of the aqueous humor. The projecting tips from its anterior portion, seventy or eighty in number, are known as the ciliary processes.

2. The muscular part, known as the ciliary muscle, which consist of involuntary fibers which cause the ciliary muscles to play an important part in the accommodation of the eye. The fibers of the ciliary muscles are arranged in two sets: the meridional and the circular.

The anterior portion of the eyeball, that is, the space included between the cornea in front and the crystalline lens and ciliary processes behind, is filled completely with the aqueous humor. The iris is completely immersed in this fluid.

The vitreous humor occupies four-fifths of the interior of the eyeball. It is a thin jelly-like albuminous fluid inclosed in a delicate transparent membrane, called the hyaline membrane.

The vitreous humor is admirably adapted to maintain the form of the eyeball and give to the retina, which is spread upon its outer surface, the necessary support, while at the same time it yields sufficiently to protect this delicate structure from injury by jarring or external pressure. It also keeps the choroid and retina in position, so that the latter shall be at the proper location to receive the images formed by the refracting media.

The crystalline lens is a transparent, double convex lens, the convexity being greater on its posterior than upon its anterior surface. It is situated immediately behind the pupil and in a depression in the front part of the vitreous humor. The lens in its capsule (hyaloid membrane) is suspended at all portions of its circumference, and is retained in its position chiefly by what is termed the suspensary ligament of the lens, which originates in the meshes of the ciliary body, and is firmly inserted at the edge of the capsule.

The consistency of the crystalline lens is such as to allow its shape or convexity to be readily altered, this contraction and expansion being accomplished by means of the ciliary muscle. The crystalline lens becomes denser with age, and hence it is less susceptible to the action of this muscle. The function of this lens enables one to see objects clearly defined within a long range of different distances from the eye.

The iris is a thin, circular-shaped, contractible membrane, suspended in the aqueous humor behind the cornea and in front of the crystalline lens. It is perforated slightly to the nasal side of its center by a circular aperture, the pupil, for the transmission of light, thus forming a diaphragm with variable aperture. The word iris means rainbow; it receives this name from its various colors in different individuals.

It is an interesting fact that eyes of new-born babies are always blue, and they do not begin to assume their permanent

color until the sixth or eighth week of life, the color being then formed by the addition of a greater or less amount of dark pigment.

The eyes of albinos are pink on account of lask of pigment. The sight of such an eye is always deficient, and it is painfully sensitive to light.

There is a popular notion that dark eyes are stronger than light ones; the only foundation for this idea is the fact that they are better protected against excessive light. Light eyes prevail among northern nations, and dark eyes among the races who live in the glare of a tropical sun.

The muscular system of the iris is involuntary; that is, it is not under the control of the will, and hence we are not able to change the size of the pupil by the strongest effort of our volition. The muscles of the iris consist of circular and radiating fibers, known as the sphincter and dilator. The former surround the margin of the pupil on the posterior surface, these are the fibers that contract the pupil. The radiating fibers converge from the circumference toward the center, where they blend with the circular fibers, and by their action enlarge or dilate the pupil Through the action of these two sets of muscles the pupil has the property of changing its size, thus regulating the amount of light admitted to the retina. The contraction of the pupil through the sphinctor muscle is controlled by the third cranial nerve, the dilation through the radiating fibers by the sympathetic nerve. Thus we have the means to counteract strong light and to correct insufficient illumination within reason.

The internal or nervous coat of the eyeball, called the retina, is the most important membrane of all; indeed, all the other structures of the eye may be considered subservient to this one, as on it are formed the images of external objects by means of which we are said to see them. The retina is continuous with the optic nerve; in fact, it seems to be the spreading out of the nerve, which pierces the sclerotic and choroid to form this membrane, and by means of which the impression is carried to the brain, and hence the eye and the brain are in the most direct and constant communication.

In the center of the posteria part of the retina, at a point corresponding to the axis of the eye in which the sense of vision

is most perfect, is a round, elevated, yellowish spot, having a central depression at its summit, called the fovea centralis, which is the center of direct vision and the most sensitive part of the retina. The retina is provided with a large number of nerve-end-organs called tht rods and cones according to their shape. In the region of the macula lutea (which is the Latin term for yellow spot) the rods begin to be replaced by the cones, so that at the macula there are no rods at all, while the number of cones is great, which, therefore, makes the latter the most prominent feature of the fovea. About one-tenth of an inch to the inner side of the yellow spot is the point of entrance of the optic nerve, which is the only portion of the surface of the retina from which the power of vision is absent.

The retina in its entirety is a very delicate and extremely complicated structure consisting of ten layers; time will not allow us to go further into details as to these layers.

The optic nerves (the second pair of cranial nerves), after leaving the eyeballs, run obliquely backward and inward through the orbit of the optic foramen, through which they pass into the cranial cavity, where they join together to form the optic commissure, in which there is a decussation of the nerve fibers, and then pass on backwards to form the optic tracts.

These tracts extend from the commissure to the base of the brain, finally entering the geniculate bodies, the optic thalmai and the corpora quadrigemina.

A great deal more could be said about the anatomy of the human eye but what has been explained will give us some idea as to the wonderful piece of work nature accomplished in order to bring about vision..

The sense of sight is the most remarkable of all our senses, both for the special nature of the impressions which it receives, the complicated structure of its apparatus, and the variety and value of the information which it affords with regard to external objects.

It is by this sense that we receive the impressions of light and color, with all their modifications of intensity and combination, and acquire our principal ideas of form, space and movement.

Let us now observe for instance the effect of illumination upon this visual organ when pursuing our daily work. Consider a mechanic working at a lathe with an electric lamp (clear bulb) and no screen, as we often observe, suspended from the ceiling hanging close in front of his face. The bright metal parts upon which he is working reflect a strong light directly into his eyes, causing the ciliary muscles to contract the iris in order to protect the vital organs from the glare; the next thing which may happen is that the man looks for some tools in a dark spot and, consequently, the ciliary muscles will again be called upon by the nerve action to go to work and expand the iris in order to allow sufficient light to enter the eye to render vision possible. If this process is often repeated, and in the daily work it frequently sulting ultimately in eye strain and fatigue. With the eyes exposed to unprotected clear lamps vision is impaired and this mode occurs, the ciliary muscles are taxed to a very high degree, reof illumination must be considered a great offense to our visual organs. It is a wonder that more suffering is not recorded.

Insufficient illumination represents another abuse of the eyes, and a careful regulation of the illumination in our factories, offices, homes etc., should be observed in order to support our eyes in their functioning. How can this best be accomplished? The answer must be: "Study Daylight Effect."

1. Dark corners should be illuminated with diffused indirect light of sufficient intensity in order to prevent excess of contrast of all illuminated objects in areas surrounding them.

2. The eyes should not be exposed to direct light sources of any kind.

3. The excess of the yellow light from most of our artificial light sources should be neutralized by blue filters of suitable tint in order to approach daylight color. It is not necessary to obtain absolute standard daylight quality as determined spectroscopically, since our light sense overcomes a considerable variation of color combinations in the light source without experiencing fatigue.

4. When work is to be done on bright light reflecting surfaces, the illumination should be as much as possible of a grazing incident so that the light rays may not reflect direct into the eyes of the worker.

5. Cheerful surroundings, well illuminated, add a great deal to the comfort of the individual, remember that seeing is a nerve action.

6. Attractive soft color schemes of variety in work rooms will prove to be refreshing to the eye; monotony in color should be avoided.

7. Neither red walls nor pure white walls are inviting; the former tend to fatigue, the latter glare and tire the eye. Neutral gray as a base color is restful to our eyes while bright multiple color effects are exciting.

8. Fine detail work does not demand brilliant illumination, a soft velvety light of moderate intensity will prove far more satisfactory in order to prevent eye fatigue. For extreme fine detail work optical appliances should be made use of in order to magnify the images of such objects on the retina; illumination alone will not suffice. The illuminating engineer should also make frequent use of the spectroscope in testing light sources since one cannot judge by tint only.

SOME PROPERTIES AND LIMITATIONS OF OPTICAL MATERIAL*

BY W. B. RAYTON**

The Optical Engineer is confronted with problems of two general types. First, the problems dealing with distribution of light and, second, the problems involved in the formation of images.

The first group includes the requirements of the ophthalmologist who wants a beam of light of almost infinitesimal cross section but of high intensity to project into the human eye, the exacting requirements of the microscopist in illuminating the objects on the stage of his microscope, of the moving picture engineer in illuminating his film, of the illuminating engineer in lighting a factory yard, and of military and naval men in projecting beams of light of high intensity for many miles.

The second group of problems includes those involved in the design of lenses for microscopes, telescopes, field glasses, photography, projection, engineering instruments, spectroscopes and a host of other instruments as well as for the correction of defective vision. There are very fundamental differences in the nature of the images required by different instruments but there are, again, two general classes into one or the other of which most images will fall. There is a group of instruments, of which the most conspicuous examples are the microscope and the telescope, in which the most important requisite is the utmost perfection of definition over a relatively small field of view. In the second group, an extensive field of view is a prime requisite and in order to secure tolerable definition at the margin of the wide image it is necessary to sacrifice some of the excellence of definition otherwise possible at the center of the image. To this second group belong photographic and projection objectives, spectacle lenses, eyepieces of all kinds, some telescopes, such as submarine periscopes and opera glasses, magnifiers, and reading glasses. The statement that central definition has to be sacrificed in the interest of improvement in marginal definition must not

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**Bausch & Lomb Optical Co., Rochester, N. Y.

be misunderstood. The fact is, that for the most part, extremely good definition is not required in the center of the field. To illustrate: the image formed by a telescope objective may be required to retain good definition ever though magnified fifty times by the eyepiece, while the image formed by a photographic objective is generally viewed with the naked eye and very rarely is required to stand a magnification as great as four.

The elements with which the optical engineer solves his problems are very few in number: mirrors, prisms, and lenses. The raw materials from which they are made comprise optical glass, and a few crystals such as calcite, fluorite, rock salt, and quartz. The variables at his disposal in the solution of a problem are: number of elements employed, properties of materials used, angles of prisms, curvatures of mirror and lens surfaces, and separations of elements.

Of the raw materials mentioned, optical glass is by far the most common. Crystals are used very rarely. They are expensive and difficult to work but they meet certain requirements which cannot be met by any glass yet produced. Optical glass differs from ordinary bottle and window glass in its transparency and homogeneity and in its refractive properties. The index of refraction for yellow light varies from 1.50 to 1.75 in the majority of glass catalogs and for each index of refraction there is usually some choice as to dispersive power. The measure of the dispersive power of a glass is the difference in its indices of refraction for light of different colors.

In the design of an instrument, be it a magnifier, a compound microscope, or a submarine periscope there are two stages in the process. One involves the determination of the focal-lengths, positions, and diameters of the lenses and the apertures and locations of stops to limit the size of the light beams. The second stage involves the selection of materials, curvatures, lens thicknesses, prism angles, etc., to the end that the performance of the complete instrument shall measure up to the required degree of excellence in the simplest and most economical manner.

The elementary theory by means of which the first of these stages is covered is found set forth in most text-books on Physics and Optics. The second stage is not so well covered in the literature. There are, to be sure, huge volumes available filled

with astonishingly complicated equations whose solution is said to lead to a determination of the radii of curvature and properties of glass required to fulfill certain simple requirements but they are of little value to the practical designer and are misleading to the amateur. For the most part, the second stage requires a training which can be secured only by experience. Our present science of mathematics is not powerful enough to solve problems which to an experienced lens designer armed with a table of logarithms and logarithmic functions of angles offer no difficulty whatever.

The optical elements employed were said to consist of mirrors, prisms, and lenses. It is probably a matter of some interest to know something of the purposes which these different elements serve.

Mirrors are called plane, spherical, parabolic, or elliptical according to the nature of the surfaces ground on them.

If made of glass, they are called first surface or second surface according to which surface is silvered. Ordinary mirrors are invariably second surface mirrors for the reasons that silver unprotected from the air, as it generally is in the case of first surface mirrors, rapidly losses its originally high reflecting power because of oxidation and sulphation and is easily scratched and, in fact, may be entirely removed in attempts at cleaning. Inasmuch as there is some light reflected from the front surface as well as from the back surface, second surface mirrors give rise to double images. First surface mirrors are used when double images are objectionable. When other considerations permit, the silver may be protected by a thin coating of transparent lacquer. This is very effective in preventing the silver film from tarnishing but it is very soft and easily scratched in any attempt to wipe dust from the surface. Mirrors for reflecting telescopes and for some other purposes are sometimes made of metal. Such mirrors are much more resistant to atmospheric attack than silver on glass but have not so high a coefficient of reflection.

In addition to the every day use of plane mirrors, they find limited employment in optical engineering in changing the direction of beams of light. Spherical and parabolic mirrors find their principal use in collecting a wide beam of light diverging

from a light source and transforming it into an approximately parallel beam such as in automobile headlights and in searchlights. The degree of approximation to parallelism is governed by the angle subtended at the center of the mirror by the source of light, the nature of the mirror and the quality of its surfaces. In a spherical mirror, the focal points for different zones are situated at different points along its axis, therefore, it is impossible to place a light source at any one point such that the rays of light after reflection by the mirror are parallel to its axis except for one zone. Parabolic mirrors are not afflicted with this defect. On the other hand it is technically impossible to produce parabolic surfaces of the high quality attainable in spherical work except at a staggering cost. Even granting the inferior surface quality, parabolic mirrors are very much superior to spherical mirrors in producing parallel beams. Even a parabolic mirror of perfect surface quality, cannot produce an absolutely parallel beam by reason of the fact that the light source always subtends a finite angle at the center of the mirror. The smaller the light source and the longer the focal length of the mirror, the less will be the spread of the beam. Since light sources of infinitesimal dimensions are impossible, a strictly parallel beam of light is a physical impossibility.

Prisms are of two kinds: first, those used for the refraction and dispersion of light into its component colors such as find use in spectroscopy and, second, prisms used as substitutes for plane mirrors. The latter application is much more common than the former. There is a great variety of types of reflecting prisms and they are adapted to a wide range of purposes. Prisms are superior to mirrors in many ways, differing in this respect from "substitutes" as a class. They are permanent, usually more efficient in reflecting power, and can often be made in one piece to serve a purpose which would require several mirrors. Any consideration of reflecting prisms sufficiently exhaustive to merit reading would, in itself, require more time than has been allotted to this whole paper. It must be said, however, that the theory of reflecting prisms constitutes one of the least difficult and most fascinating branches of optics.

Lenses are characterized, in the mind of the optical designer, principally by the variety and degree of difficulty of the problems

they offer. There are two facts which are responsible for this; first, the same piece of glass has different refractive indices for different wave lengths (colors) of light and, second, the effect of a refracting surface depends upon the sine of the angle of incidence. The first gives rise to chromatic aberration which manifests itself by fringes of color bordering the edges of an image. The second gives rise to the evils known as spherical aberration, coma, astigmatism, curvature of field, and distortion which manifest themselves in indistinctness or haziness of the image or in a failure to secure in the image geometrical similarity to the object.

In what follows, the term "lens" will be understood to apply not only to a single lens but to any combination of single lenses assembled as a unit. A photographic objective comprising four to six elements, and a microscope objective comprising possibly as many as ten will be spoken of as "lenses."

In planning a lens, the first question to arise is whether it is to be achromatic. It must not be assumed that this is always even desirable. In general, if it is not necessary that the lens be achromatic, it is desirable that it should not be both from the standpoint of economy and of better optical performance in other respects. If the lens is to be used as an element of an illuminating system, as a spectacle lens, or as a collective lens it need not be achromatic. Many single lenes are used as magnifiers, mostly from considerations of economy for, here, achromatic lenses are distinctly superior. Lenes whose function it is to form an image which is to bear subsequent magnification or which for any reason must be reasonably well defined must be achromatic. The closest attention to achromatism is necessary for telescope, microscope, and photographic lenses.

Simple achromatism can generally be achieved by making the lens of two elements, whose focal lengths are unequal and which are made from two glasses of different dispersive power. The focal lengths of the elements and the dispersive power of the glasses are the variables upon which the designer must depend for securing freedom from color.

Of the other image defects listed above, spherical aberration is of primary importance. If present in serious amount it blurs the whole image. Its magnitude depends upon the kind of glass,

the aperture and the focal length of the lens, the object distance, and the shape of the lens. It cannot be eliminated from a single lens but can be reduced to a minimum by a suitable choice of shape.

Practically every achromatic lens by virtue of its construction can be corrected for spherical aberration and, in fact, the name "achromatic lens" has come to imply correction of spnerical as well as of chromatic aberration.

Spherical and chromatic aberrations can both be corrected in a lens of two elements and by suitable choice of glasses the curvature of the surfaces may be so chosen that the two elements can be cemented together. This is the usual small telescope objective construction. It is generally satisfactory for cases which do not require a field of view larger than five or six degrees and for focal lengths not less than six, preferably twelve to fifteen, times the aperture, The successful treatment of spherical and chromatic aberrations for lenses of still shorter focal length compared to aperture is the problem of the designer of microscope objectives. Here the focal length may be less than half of the aperture and the elimination of these two aberrations then taxes to the utmost every resource of the designer and requires the employment of many more than two elements and in some cases it can be accomplished only by the powerful aid of crystals in addition to the usual optical glasses.

Manufacturers are very frequently asked for quotations on achromatic lenses of ordinary telescope objective construction with apertures nearly equal to the focal length. Such lenses are impossible. If any degree of excellence is required in the image, the focal length must be at least six times the aperture, while for the roughest kind of work it is possible to design lenses whose focal length is three times the aperture. They cannot be well corrected, but serve for some purposes.

The remaining aberrations, coma, astigmatism, curvature of field and distortion concern the margin of the field only. Except in very rare cases they are not of serious consequence unless the image covers more than six degrees. They are not automatically eliminated by correcting chromatic and spherical aberrations but on the other hand may be increased thereby.

Their complete or partial elimination depends upon the skillful choice of number of elements, curvatures, kinds of glass, separations of elements and size and location of stops. For a given focal length, increase of aperture increases the amount of several of these aberrations and the difficulty of treating them and eventually reaches a point beyond which the designer is unable to go.

The most familiar application of lenses covering an extreme field of view lies in photography and in the projection of lantern slides and motion pictures. It is well known, that the brightness of the image on the plate in photography or, to a certain extent, on the screen in projection depends upon the aperture of the lense and to the end that exposure time may be decreased and projected images be brighter lens designers have constantly striven to produce lenses of larger and larger aperture. Lenses whose focal length is not greater than 2.5 times the aperture are now available for moderate fields of view and 4.5 times the aperture for fields of view of fifty to sixty degrees. Still larger fields can be covered by lenses of smaller aperture.

None of these lenses affords the excellence of definition at the center of the image that is expected of a good telescope objective; no matter how fine they may be for the purpose for for which they were designed and no matter what they may have cost, they cannot give satisfaction as a telescope objective to one who is acquainted with good telescope images.

Single lenses are found in a variety of shapes. They may be plane on one side, both surfaces convex or both concave, or one surface may be convex and the other concave. Although they may be of the same focal length and diameter a group of lenses of these different shapes will differ substantially in optical performances. The decision as to which form should be used must be rendered according to conditions. Cost of manufacture may be an item. For quantity production the form with curves both of the same sign is cheapest, the form with one side plane is next, and the meniscus form with one surface convex and one concave is the mose expensive. In regard to performance, consideration must be given to the size of the field of view required. For larger field the meniscus shape used in conjunction with a stop at some distance from the lens gives the best

image. For smaller fields the other forms are better, the choice of the precise shape depending on the distances of the object and image from the lens. If object and image are symmetrically located with reference to the lens, an equilateral form is preferable; if the object is at a great distance the plano convex or concave form is better.

In general, the employment of two lenses instead of one will result in better image quality by virtue of distributing the requisite power over four surfaces instead of two. This is a means, too, of avoiding the necessity for making lenses of excessively curved surfaces. There is a very definite limit to the diameter attainable in a lens of a prescribed focal length. It is obvious that the sphere is the absolute limit beyond which the manufacturer cannot go. In practice the focal length of double convex or concave lenses should not be less than 1.5 times the diameter.

The optical performance of a lens depends not only on its construction, its design, but also upon the class and quality of workmanship employed in its manufacture. There is a substantial difference between the significance of the words "class" and "quality" as here used. There are any number of possible classes of workmanship while in each class there may be good or poor or indifferent quality. The product of a first rate workman in one class of work may be much poorer than the output of the poorest workman in a higher class of work. A customer is entitled to reject goods if the quality is not up to standard but not because he has prescribed or accepted quotation on a class of work which is not high enough for his purpose.

The class of workmanship on a lens or mirror governs the accuracy of the surfaces, of its linear dimensions, and of the centering. By accuracy of surface is meant the degree to which it approaches an absolutely spherical or plane surface. The surfaces of the least expensive class of ground and polished work are controlled by applying gauges made of thin sheet metal curved to the prescribed radius. If by the senses of sight and touch the surface appears to fit the gauge it is acceptable—its quality is satisfactory. For higher classes of work resort must be had to more sensitive methods of testing. A convenient method is based upon the fact that if two pieces of glass are brought into

contact along surfaces which approximately fit each other, the deviations from a perfect fit are demonstrated by bands of color if the surface of contact is viewed in white light or by alternate light and dark bands if viewed in monochromatic light. The color is due to interference of light reflected from the two surfaces said to be in contact but actually separated by a thin film of air. A change in color is due to a change in thickness of the air film so that bands of different colors indicate that the surfaces are not entirely parallel. If two bands of the same color are visible the thickness of the air film differs between the positions of those two bands by one half of a wave length, about 0.000013 inch. The highest class of work requires that no change of color be visible over the whole area. Such a surface must, therefore, be truly spherical or plane to within, at the most, a quarter of a wave length of light.

A surface, which by the gauge test, appears to be perfect will probably appear unbelievably bad by the more sensitive test. There are, of course, any number of intermediate grades.

Now the difference in cost between these extreme grades or classes of surface is very large. The cost of producing the cheapest surface can be very accurately estimated. The production of the highest grade involves too much of uncertainty to make accurate estimates possible but it is probably fifteen to twenty times as costly as the other. In view of this fact, it is not at all surprising if requests for quotation on "absolutely perfect" small double convex lenses are productive of astonishing results.

The optical performance and incidentally the cost are also influenced by the accuracy required in thickness, focal length, diameter and centering. In a perfectly centered lens, the line joining the centers of curvature of the two surfaces passes through the geometrical center of lens.

Inasmuch as glass is a highly elastic substance it is very difficult to produce and to guarantee the permanence of surfaces of high grade on thin pieces. For first class work, the thickness of the glass must be equal to at least a tenth of the longest dimension on the surface.

Prisms are graded according to surface quality and angle accuracy. Surface accuracy is subject to the same conditions as

pertain to the surfaces of lenses or mirrors. Angle accuracy may be demanded anywhere from tolerances of ten minutes to half of a second. In regard to cost, there are two groups with slowly rising costs within the groups and a big jump between them. Taking the cost of producing an angle accurate to within ten minutes as a basis, it costs about 60 per cent more to reduce the error to two minutes, and three to four hundred per cent more to reduce to error to thirty seconds. From thirty seconds on the rate of increase is slower again, approaching more the rate from ten to two minutes until the permitted tolerance is reduced to half of a second. Beyond this, it is practically never necessary to go.

It must be obvious that a request for prices on optical material without intelligent specification of the degree of accuracy wanted is very difficult for the manufacturer to answer. The lamentable fact is, however, that very few such inquires mention the matter at all and those that do generally employ such expressions as "absolutely flat," "absolutely parallel," "perfectly centered," and others all of which are of no value to the manufacturer. "Absolute" and "perfect" are words which have no meaning in a workshop. It happens, as often as not, that these expressions are employed when, actually, the cheapest grade of work would be entirely satisfactory. If the purchaser is unable to specify the degree of accuracy he requires he can, at least, state the purpose for which the material is required and the manufacturer can then exercise his judgement in the light of his own experience.

DISCUSSION.

LOUIS BELL: Mr. Chairman, I think we are very much indebted to the author for giving us a vivid idea of the character of the work required in these optical designs and in their execution. It is a thing which comparatively few people have any conception of, and as regards ordinary usage, the ordinary apparatus with which the illuminating engineer has to deal in his final work, requiring nice instruments, it is a mighty good thing to realize the difficulties that we are putting up to our friends, the optical constructors, when we ask for anything out of the most ordinary range of accuracy.

Within a very limited degree of precision, precision set by an optical gauge, things can be turned out perfectly, but as you will see from this demonstration, when it comes to real precision, taking it down to a fraction of a wave length of light, the troubles multiply indefinitely. I might especially call your attention to the fact that in lenses and lens sizes, the chief difficulty from a constructional standpoint comes when you begin to ask for high aperture, *i. e.*, taking a very short focal length, in respect to the aperture. The ordinary telescope works at about F/15 and the ordinary photographic lens would work down gradually from that point. In the old portrait lenses they reached F/2.5.

I believe there was a lens put out just before the war by Zeiss that got down to F/1.5. I never was able to see one, but I have heard of it. The difficulties, however, increase with enormous rapidity, as the relative aperture also increases, and that is why the highgrade photographic lenses are so troublesome, and expensive to make. Moreover the corrections toward the outside of the field get more and more difficult to get with the photographic lens. Twenty or thirty degrees is easy, thirty to forty, difficult, while forty to fifty is decidedly a stunt. As the aperture still goes running up, the practical size of the field constantly runs down so that with a lens of F/2.5, passable definition can only be obtained on a very limited area and as it is pushed down,further the area gets smaller and smaller and smaller.

The limitation lies not only in the characteristics of the glass, but also in the fact that no assemblage of spherical surfaces can absolutely get rid of the last spherical aberrations. There is always a faint residual that is left somewhere, and the only difficulty is to keep that out of range of the region where you want to work.

Two hundred years ago and more, Descartes called attention to the importance of aspherical curves in curing spherical aberrations, and for fifty years lens makers, with the crude means at their disposal, did their level best to produce aspherical surfaces to get rid of the last stages of spherical aberrations. You can get rid of practically all of it for most purposes, but in the highest grade of astrophysical objectives, the constructor is now and then driven to a final aspherical correction. In fact, some of the distinguished workers in that line go as far as to say that no astro-

physical objective of the highest quality leaves the maker's hands, after they have worked it down to the last limit of perfection, with all the surfaces truly spherical.

Aside from that difficulty, which really pertains only to attempts to get extra wide field, the great outstanding trouble is the abolition of the last trace of chromatic aberration. We have now, thank goodness, a group of glasses which get rid of most of the so-called achromatic combinations for telescope. Now, as a matter of fact, they leave perhaps fifteen or twenty per cent of the outstanding spectrum still doing business, and the best of them, in the constructions involving three lenses of highly peculiar glass, don't quite get rid of it.

The great difficulty beyond that is the question of getting a flat field and in telescope objectives, the flat field is never obtained. In the astrophysical objectives and some ordinary photographic ones we get mighty near to a flat field, but the curvature of the field and spherical aberration is still the constructor's nightmare, and while he may succeed over a fairly wide area, as soon as he attempts to stretch his limit, the flatness of the field falls off and the definition disappears. I think some day we possibly may get even better glasses than we have now for the purpose, but I mention these things merely to point out how formidable a task the optical constructor has, and the infinite credit he deserves for turning out the lenses which are now available for most purposes for which physicists want them.

M. Poser: I have nothing to add to Mr. Rayton's paper, but there is one point I should like to mention, and that is the possibility of increasing the aperture of a lens by making use of aspheric surfaces. Such lenses have been made, and good results obtained, as for instance in condensing lens systems, ophthalmic lenses, etc., but when it comes to the application of aspheric lenses in highly corrected lens systems, almost unsurmountable difficulties arise, and I believe we are still a long way off from the ideal lens having aspheric surfaces in order to gain larger apertures, and still retain the high quality correction we have to-day with lens systems computed with spherical surfaces.

Dr. G. S. Crampton: I would like to ask Mr. Rayton to explain the inherent difficulties in manufacture of parabolic lenses and mirrors.

W. B. Rayton: There are two difficulties in the production of parabolic surface lenses, one in the building of machines which will generate parabolic surfaces in the sense that the grinding machines already in existance generate spherical surfaces. It isn't a geometric impossibility to generate a parabolic surface, but it is, so far, practically impossible to build a machine that will grind and polish, especially polish, parabolic surfaces of anything like the degree of quality that we can get on spherical surfaces.

The second difficulty lies in devising an easy and satisfactory method of testing the surface. The method that I attempted to show you by projection, provides a very sensitive means for testing spherical surfaces. Test-glasses, so-called, can be produced to any desirable degree of accuracy of surface. Although we may not know the absolute radius of curvature we do know that their surfaces are truly spherical. The fitting of one of these test-glasses to a lens surface is generally accomplished by a sliding motion which is possible in the case of spherical surfaces but impossible in the case of parabolic surfaces. If we made a parabolic test glass, it would fit the paraboloid to be tested only when the axes of the two paraboloids coincided. The least motion one way or another throws it out of contact.

We are quite successful in making shallow parabolic surfaces for searchlights; such surfaces deviate from the spherical by only a slight amount. For grinding and polishing strong, deep parabolic surfaces it must be said that the technique is not yet developed. It may come in time. Whatever can be said of parabolic surfaces can be said with ten times the emphasis, for aspherical surfaces in general. The parabola is, at least, a well-known geometrical form expressible by a fairly simple equation.

The aspherical surfaces which have been mentioned are not conic sections, nor are they very often expressible by an equation, no matter how complicated. You can easily surmise the difficulties presented by such cases.

Louis Bell: I might perhaps sum up some of the difficulties of a spherical surface by quoting a remark of Sir Isaac Newton in a letter when the subject of parabolic mirrors was under discussion. Sir Isaac remarked, with great truth, that

there was no geometrical way of grinding a paraboloid, but he had some idea that perhaps a machine could be developed to do it; and he feared the production of parabolic surfaces to be an operation of so great difficulty that he absolutely threw up the notion in the construction of telescopes and adhered to spherical curves.

ILLUMINATION AND TRAFFIC ACCIDENTS*

STATISTICS FROM THIRTY-TWO CITIES.

BY EARL A. ANDERSON AND O. F. HAAS**

The seriousness of accident hazard on streets of American cities as a factor to be reckoned with in every day life becomes evident from even a casual inspection of statistics which show the losses incurred in this continuous waste of life, time and property. For example, in a recent paper Simpson[1] gave figures showing 25,000 fatal industrial and 2,000,000 total industrial accidents annually causing lost time of a total cost of $2,000,000,000 or a cost averaging $1,000 per accident. The total annual fatal accidents from all causes including industrial are estimated to be 75,500 from statistics compiled by Dr. Crum,[2] and of these approximately 7,800 are railway and 15,500 are street traffic accidents. Therefore, the loss of life in traffic accidents is twice as great as in railway accidents and equal to over half the total industrial loss.

As to an evaluation of the annual personal and property loss from automobile accidents in terms of money, Dr. Crum states that while an accurate computation is not possible, the annual sacrifice is fully $1,000,000,000. This figure appears very reasonable when one considers that in the survey of traffic accidents numbering 800 fatalities reported in this paper there are 31,000 other accidents of sufficient severity to be reported to the police and that personal injuries were sustained in approximately one-half of these cases.

To the development of high speed traffic brought about by the very extensive adoption of automobiles must be charged practically all of the increase in street traffic accidents. In 1906

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** Engineering Department, National Lamp Works of General Electric Co., Cleveland, O.

[1] R. E. Simpson, Travelers Insurance Company—I. E. S. TRANSACTIONS, Vol. XV—No. 8.

[2] F. S. Crum, Statistician, Prudential Insurance Co., Automobile Fatalities.

there were less than 400 deaths in the United States from automobile accidents, while in 1920 the total was greater than 10,000, representing an increase of 2500 per cent. Further, as shown by the curve of Fig. 1, this total is mounting steadily. In recent

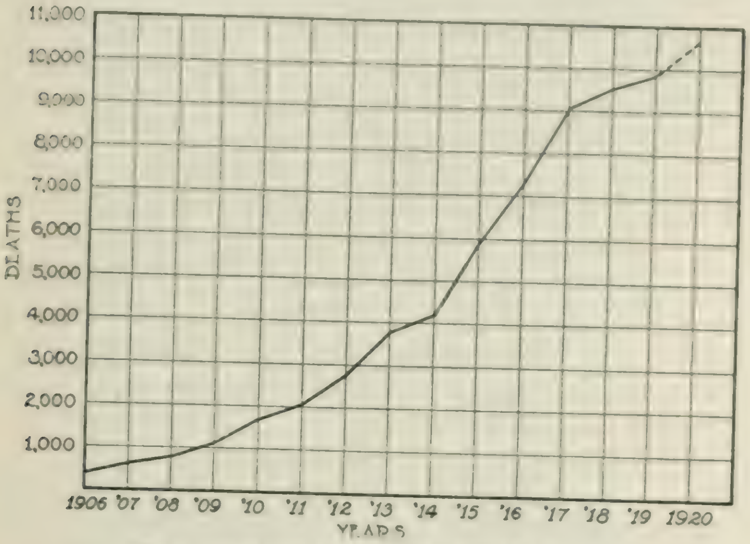


Fig. 1—Deaths from Automobile Accidents by Years.

years efforts have been directed toward reducing the accident rate by more stringent traffic regulations and by widespread educational publicity work on the part of safety organizations. Definite evidence of the value of such safety measures may be seen in statistics which show a check in the growth of the accident rate in those cities and localities where the most careful attention has been given to the development of accident prevention efforts.

The figures presented by Dr. Crum show that at least two-thirds of all traffic accidents have occurred in cities of 10,000 inhabitants or more and on this basis it would appear that the traffic accident problem is of greatest immediate importance in these larger communities. It is worthy of note, however, that the increasing amount of inter-city touring has brought a heavy highway traffic to villages of even the smallest size and it is, therefore, apparent that even in smaller communities public safety

demands an increased attention toward means for reducing the street traffic accident hazard.

The purpose in instituting the survey reported in this paper was to obtain, if possible, some definite measure of the value which should be attributed to the proper illumination of streets as a factor in the prevention of traffic accidents. In order to obtain as high a degree of uniformity as possible in the collection of the data, blank forms were prepared providing for a charting of all traffic accidents in a given city during the period of one year and for distributing them as to the month and hour of the day at which each occurred, with notations as to whether or not the accident resulted in a fatality. A representative group of cities was selected and individuals in each who were known to be interested in problems of public safety were requested to arrange for the tabulation of the data. The work of tabulating accidents from the city records was often tedious on account of the way in which the accident reports were filed. In some instances the accident data were not available. The very cordial response to the request for cooperation in this survey is, however, attested by the fact that tabulated reports in form to be directly applied were obtained from 32 cities with a combined population of over 7,000,000. From each of these cities the report covered a full year's accidents; in most cases during the period from the middle of 1919 to the middle of the year, 1920. The names of the cities and an abbreviated summary of the data for each city are given in the accompanying tabulations. The total number of street traffic accidents reported for one year in these 32 cities was 31,475 of which 9,534 or 30.3 per cent occurred during hours of darkness. It was anticipated that there might be considerable variations in conditions existing in individual cities located in different states and it was, therefore, particularly desired to obtain a sufficiently diverse group of cities including a large enough total of population to give the presumption of a reasonable degree of accuracy in the results.

The 31,475 traffic accidents are charted in Fig. 2, according to the total number during each month. In certain cities special local influences, such as an excess of traffic at some one season of

the year, changed the distribution of accidents considerably but in most cases the individual reports adhered to the trend shown by the average curve in Fig. 2. At first thought it is somewhat surprising to note that there were a greater number of accidents in the Summer months than in Winter as there are a number of influences which tend to increase the hazard in Winter, such as stormy foggy weather, slippery streets, and the impediment of heavy clothing. However, as a matter of fact, the traffic is so much greater during Summer months than in Winter that even in spite of the unfavorable conditions in Winter the accidents are more in the Summer than in the Winter months in most cities.

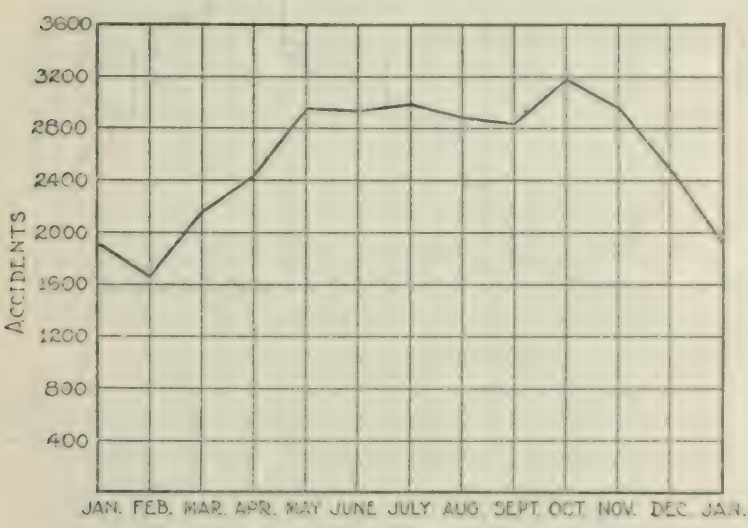


Fig. 2 Traffic Accidents by Months.

The total accidents reported for the year are charted in Fig. 3, according to the hour of the day during which they occurred. This chart also shows the apparent importance of density of traffic as a factor in causing accidents. It will be noted that relatively few accidents are reported in the hours from 1 to 7 o'clock in the morning, the period of the day in which street traffic is least. On the other hand, the accident rate becomes greatest in the hour from 5 to 6 in the afternoon when in practically every city the streets are congested with the home going population from offices, stores and factories.

An obvious and simple way of determining how many of the 9,534 accidents which occurred after dark would have been avoided had daylight or its equivalent been available, is to compare the accidents which occurred during the hours in the evening which were daylight in Summer with the number of accidents

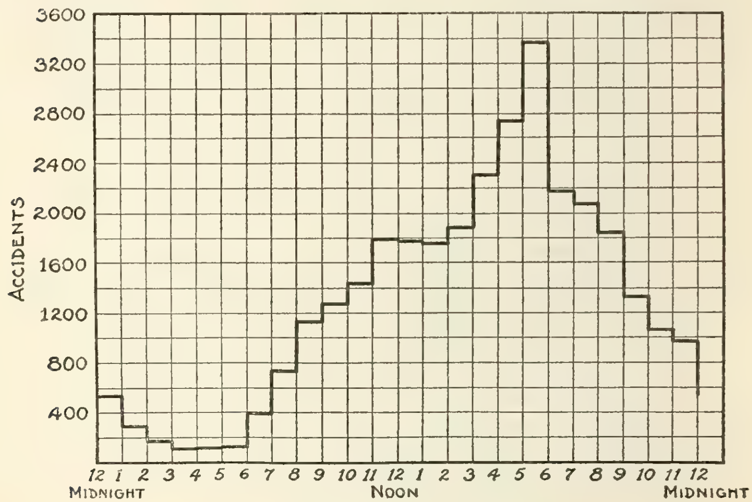


Fig. 3—Traffic Accidents by Hours.

which occurred during the same hours in Winter when because of the shortness of the day it was dark. Consultation of tables of sunrise and sunset applying to the different cities involved indicated that the hours 6 to 8 P. M. were the two hours of the day which are fully light in the months of May, June and July and entirely dark during the months of November, December and January.

It is evident, however, that a ratio between the accidents occurring from the hours 6 to 8 P. M. in Summer as against the number that occur during the corresponding hours in Winter would not directly show the influence of light because of the numerous other variables referred to above which have an influence that must be taken into account.

Fortunately the accident statistics for the hours of the day which are light in both Summer and Winter or which are dark in both Summer and Winter offer a convenient means for determin-

ing a correction factor to take into account the variables other than light which effect the number of traffic accidents in Winter and Summer. The periods of 3 to 5 P. M. and 9 to 11 P. M. are the logical selections because of their adjacency and the consequent similarity of traffic to that in the 6 to 8 P. M. period. In the accompanying tabulation are shown the data on accidents by cities and the totals for the respective periods of 3 to 5 P. M., 6 to 8 P. M. and 9 to 11 P. M., separated so as to show the number of accidents during these hours in the "Summer" months of May, June and July, and the "Winter" months of November, December and January combined.

Referring to the totals in the tabulation, and taking first the hours from 3 to 5 P. M. which are daylight in both Summer and Winter, the number of accidents are found to total 1429 in Summer and 1095 in Winter. The winter accidents from 3 to 5 P. M. are, therefore, 76.6 per cent of the summer total. Considering next the totals for the period of 9 to 11 P. M. which is dark both in Summer and Winter, it is noted that the accidents are respectively 740 and 495. The winter accidents from 9 to 11 P. M. are, therefore, 66.9 per cent of the Summer total. If these two percentages of 77.6 and 66.9 are averaged it is indicated that for the group of cities in this survey, traffic conditions are such that excluding the influences of illumination the Winter accident rate in the afternoon and evening is approximately 71.8 per cent of the Summer accident rate.

Considering next the period of 6 to 8 P. M. which in Summer is daylight, there is shown a total of 1,200 accidents in the 32 cities during the three months of May, June and July. Hence, applying the average percentage of Winter to Summer accidents (71.8 per cent) determined as above* it would be anticipated that in the three "Winter" months of December, January and February, there would be 862 (71.8 per cent of 1200) accidents during the hours of 6 to 8 o'clock P. M. However, the survey

*The percentage for 6 to 8 P. M. actually is probably nearer the 9 to 11 P. M. figure of 66.9 per cent than the average of 71.8 per cent since both periods are during the evening hours. However, the more conservative figure is used. Had 66.9 per cent been used the computed percentage of accidents due to lack of light would have been 23.3 per cent.

TRAFFIC ACCIDENT STATISTICS FOR THIRTY-TWO CITIES DURING A PERIOD OF ONE YEAR.

TRAFFIC ACCIDENTS REPORTED.

	Total	Night	Total Fatal	Night Fatal	3—5 p. m. Winter*	3—5 p. m. Summer	9—11 p. m. Winter*	9—11 p. m. Summer	6—8 p. m. Winter*	6—8 p. m. Summer
Philadelphia, Pa.	5231	1485	190	66	175	251	71	98	164	183
Cleveland, Ohio	3549	1059	174	56	120	120	89	73	154	121
Boston, Mass.	3380	1001	89	38	108	159	57	69	117	131
Pittsburgh, Pa.	2950	982	6	2	119	183	57	100	74	109
San Francisco, Cal.	3014	1092	76	32	127	106	58	73	110	84
Jersey City, N. J.	672	223	28	13	18	38	8	17	36	32
Rochester, N. Y.	2570	735	29	9	70	111	34	71	62	119
Portland, Oregon	1230	411	31	8	45	43	11	21	38	48
Columbus, Ohio	193	95	17	9	7	11	6	13	8	7
Hartford, Conn.	1389	300	19	6	38	72	12	17	37	57
Grand Rapids, Mich.	255	78	12	4	9	8	1	7	10	12
Youngstown, Ohio	702	258	33	15	33	31	12	17	28	25
New Bedford, Mass.	699	189	7	3	34	40	6	17	20	31
Lynn, Mass.	818	278	7	2	35	40	19	20	36	42
Utica, N. Y.	652	150	9	3	22	43	2	25	16	33
Fort Wayne, Ind.	1010	241	9	2	42	30	14	13	29	19
Peoria, Ill.	131	26	7	3	5	11	1	1	5	1
South Bend, Ind.	143	46	6	3	6	6	5	6	7	5
Portland, Me.	620	177	1	—	16	24	9	16	20	18
Charleston, S. C.	192	52	13	3	6	8	—	7	8	3
Rockford, Ill.	181	45	11	3	5	15	3	5	3	9
Saginaw, Mich.	120	48	3	—	—	7	2	3	8	5
Holyoke, Mass.	287	79	5	2	15	13	5	2	5	15
Gary, Ind.	281	78	10	4	5	11	3	13	6	12
Malden, Mass.	187	56	3	—	3	9	—	5	3	13
McKeesport, Pa.	74	30	2	—	1	1	1	3	2	6
New Castle, Pa.	74	31	3	1	3	2	—	5	2	12
Mt. Vernon, N. Y.	264	78	2	1	11	12	3	7	8	12
Evanston, Ill.	287	81	9	4	7	17	2	7	6	11
Austin, Texas	169	75	2	2	9	3	2	2	16	9
Muskogee, Okla.	42	20	2	—	—	3	1	1	2	9
East Cleveland, Ohio	109	35	6	4	1	1	1	6	6	7
TOTAL	31,475	9,534	821	298	1,095	1,429	495	740	1,046	1,200

*Winter refers to November, December and January. Summer refers to May, June and July.

shows a total of 1040 accidents to have actually occurred during these hours in the three Winter months or 184 more than anticipated provided there had been the same effectiveness of illumination in the Winter months as in Summer. Hence, there is the strongest evidence that 184 accidents or 17.6 per cent of all those at night must be attributed to the lack of light during the winter months. Applying this same percentage to the 9534 accidents which occurred after dark in the 32 cities covered by this survey it appears that 1678 would have been avoided if adequate illumination had been provided.

Assuming that the same proportion of day and night accidents which was found to exist in this survey holds in all cities, last year there must have been out of the total of 10,040 killed, 3,223 deaths from night automobile accidents and 17.6 per cent of these, or 567 were, therefore, directly attributable to lack of sufficient illumination. In addition to this loss of life a similar computation shows that the very substantial amount of $54,000,000 of the billion dollar annual street accident loss estimated by Dr. Crum may also be attributed to lack of light. According to census reports the total expenditure for street lighting in the United States is not in excess of $50,000,000.

The percentage of 17.6 arrived at as the proportion of night accidents which may be attributed to lack of light is undoubtedly an extremely conservative figure to use in evaluating the usefulness of illumination in preventing traffic accidents, for, as a matter of fact, the streets of all of the cities covered in the foregoing survey were illuminated at night by artificial lighting of varying degrees of effectiveness. In an individual city where the need for better street lighting is especially evident the percentage of night accidents chargeable to the lack of light is likely to run as high as 50 per cent. On the other hand, in the case of those districts where fairly high levels of artificial street lighting are provided by so-called White Way systems, the percentage of night accidents chargeable to lack of illumination can be said to be fairly low. It was hoped to have data from this survey to show the difference but it was not found practical to separate the statistics for the better lighted sections in a sufficient number of cases to arrive at an average figure.

While in the present state of the art it is not practical to provide artificial street lighting approaching actual daylight levels it is entirely feasible to increase the quantity of light to a level from 3 to 10 times as high as that provided by average existing systems, and when this is done with properly installed equipment it may be confidently expected that a large measure of the benefit of light in reducing accidents will be secured.

It is, perhaps, pertinent to emphasize that these higher levels of artificial street illumination, the expenditure for which is so amply justified as an accident prevention measure, have many other important advantages in contributing very greatly to the prevention of crime, to the comfort and convenience of all those traversing the streets, and to commercial and industrial progress.

Modern illuminating engineering has been of great assistance economically in making possible "double shift" operation of industrial plants, thereby in many cases reducing the overhead charges on the investment in plant and machinery by as much as one-half. In the development of a level of street lighting such as will enable night traffic at the same density, speed, convenience and safety as by day, there is offered a similar important opportunity for community economy. Large as the expenditures are already for improved thoroughfares and highways, engineers estimate that at the present rate of traffic growth duplicate roadways must be built very soon in many districts. This congestion, however, will be greatly relieved and the time when duplicate road construction is required will be postponed for years in many cases provided a larger proportion of the traffic can be diverted from the crowded day hours. In line with this, Mr. Arthur Williams, of New York, recently presented a paper in which reductions as great as one-half in trucking cost were estimated to be possible by the increased utilization of equipment and terminal facilities and the avoidance of traffic delays by the use of streets during the less congested night hours. It is apparent that the density of traffic which would result from such a "double shift" utilization of thoroughfares and highways would greatly increase the total of night accidents. Furthermore the greater density of traffic at night would undoubtedly result in a larger proportion than 17.6 per cent of the accidents being chargeable

to lack of light, unless adaquate street lighting is provided. But the annual cost to the community of lighting entirely sufficient for safe and convenient night traffic is small indeed compared with the construction and maintenance cost of the additional roadways which will otherwise be required. In conclusion the authors wish to acknowledge indebtedness to Mr. Ward Harrison for valuable suggestions in connection with the survey reported in this paper.

DISCUSSION

A. F. DICKERSON: I think this paper will be very valuable particularly in selling street illumination or rather selling the idea of street illumination, and I am sure it could well be used by the Society for Electrical Development, and the National Electric Light Association. In my own locality, Schenectady, the majority of our accidents have been on the highways leading into the city and by far most of the fatal accidents have been at night. I recently read that on one stretch of highway, just out of Schenectady, last year there were seventy serious accidents resulting in eleven deaths. The coroner refers to this as "Death's Highway," and every effort has been made to reduce accidents by regulating the speeds, and recently there has been installed an improved highway lighting system. This system of highway lighting has been in use now for about two months, and no serious accidents have been reported at night on this particular stretch of roadway since it has been in operation.

The solution of highway lighting, we feel, is to make the highway so well illuminated that the bright lights on the automobiles can be cut out, that is, the automobiles travel at high speeds on dim lights. At the present time, we are making tests to determine just how far we can decrease this illumination in order to light economically a highway. Fixtures have been made which distribute three or four times as much light on the road surface as ordinary street lighting fixtures, and we feel that on the congested highways, at least, communities can well afford to pay the bill for this lighting. I should estimate that such lighting would cost in the neighborhood of seven or eight hundred dollars per mile per year.

In my opinion it is the duty of this Society to make a study of highway lighting and I hope that if any of you have data on this subject you will send it to me or to the Society's headquarters.

L. C. PORTER: One of the things which will go a long way towards reducing these highway traffic accidents is the introduction of the flashing highway crossing signal. No matter how good your street lighting, unless there is some characteristic signal at crossings and dangerous places, many people will fail to slow up or to realize that there is a dangerous location. A number of installations of these crossing signals have been made in places where there were previously fixed lights and where the fixed lights were smashed into time and again by automobiles. When a flashing light was set up as a crossing signal, the number of times that it was hit was very greatly reduced. In a great many cases, where there are congested crossings, the municipality cannot afford to maintain a traffic officer, but in those places, one of the flashing highway crossing signals can be installed at relatively low expense, and its maintenance is almost negligible. The signal will operate over a period of a year without attention and is effective.

These highway crossing signals have taken two forms: one for use in cities where the signal is equipped with a round diffusing globe of not very high intensity, and is visible from all directions. Out along the main highways outside of the cities the signals are equipped with lenses, generally red lenses, which can be seen for a long distance down the street and they are very effective. A system of colors has been worked out; green for cross roads, red for railroad dead ends, etc., and the head-ons will carry route numbers.

The railroads are taking up the lighted crossing signal in place of the old crossing bell. The crossing bell was adequate in the time of the horse and vehicle, but to-day it is not adequate when you are coming down the road thirty or forty miles an hour. You do not hear the bell. With some types of automobiles you can not hear it when you are close to it, but a read flashing light is effective. You can not help but see it and take warning from it.

C. M. MASSON: In my capacity as illuminating engineer for Southern California Edison Company of Los Angeles, I am often

called into consultation by engineers of the Automobile Club of Southern California. The Club has a membership of 50,000 automobile owners and with an income of $50,000 per month from dues, the Club has set aside a fund for installing all kinds of signals. It is now proposed to install at least two dozen flashing danger signals throughout Southern California under Edison lines and two of them which have been installed and operating are giving good satisfaction.

We have heard from many sources that the signals are serving the purpose of causing motorists to slow up, and that. of course, is one of the greatest preventatives of accidents that we can possibly expect to have. It has been a pleasure to report here that Mr. Porter's good suggestion has already been carried out in California. I shall be glad to let the Society know what we are doing in this line if it would be valuable for members to know about it.

E. L. Elliott: I want to ask if either one of the last speakers can describe very briefly how these flashing signals operate.

L. C. Porter: The flashing signal as first put out consisted of gas burner operated from compressed gas tank with a valve which would turn on the gas full and then turn down so that there would simply be a pilot flame burning, and then turn it up again. Those tanks were installed in steel casings and generally mounted on concrete and fitted as I stated, in cities, with a globe,. and along highways with a lens. Recently, the electric lamp has entered that field and crossing signals are being built, using low wattage lamps operated from low voltage primary batteries. These signals have a number of advantages over the gas signals which are all most obvious.

There is under development a sun valve to reduce the intensity of the lamps at night so that the signal can be made effective both by day and by night. A signal that is sufficiently brilliant to be effective in day time might become glaring at night.

Ward Harrison:—In many cities the people residing outside the main business district have to share the cost of an ornamental or "White Way" lighting system, and they are properly told that such lighting not only adds to the attractiveness and reputation

of their city, but actually reduces traffic accidents. Mr. Haas emphasized one chart in the paper which shows the very direct relation between density of traffic, which is, of course, greater in the business section, and number of accidents. This chart bears out the point that higher levels of illumination in this congested territory are desirable from the accident hazard standpoint.

If I may digress just a little, I would like to have you think of street lighting from still another angle—that is, its possible effect in the reduction of crime. Early in the year 1916 a high-intensity ornamental lighting system consisting of lanterns equipped with 1000 candlepower and 1500 candlepower incandescent lamps, spaced approximately 85 feet apart on each side of the street, was installed in the more important district of the business section of Cleveland. Although the possible effect of the improved illumination in reducing crime was but a secondary consideration at the time of the installation, the widespread increase in the last few years in such crimes as assaults, hold-ups and automobile thefts, has focused the attention on methods by which the crime situation could be remedied. It was with the thought of determining just what effect light had on the elimination of crime that a survey was made in Cleveland of the crimes committed both in the city as a whole and in the "White Way" district. More than 1000 cases of hold-up, assault to rob, burglary (buildngs entered from the front,) automobile theft, pocket picking, etc., were included in this study of the Police Department records.

It was found that 90 per cent of these crimes took place after dark. Furthermore, before the new lighting was installed, seventeen out of every hundred of the crimes were committed in the small down town area designated as the "White Way" district, which embraced less than 1 per cent of the street milage of the city. Street crimes committed after dark during the months of October, November and December of the year 1916, after the new lighting was installed, were compared with the corresponding months of the previous year so that the possible effect of the increased lighting as a deterrent to crime might be determined. In this connection it will be recalled that 1916 saw the virtual beginning of the crime wave and that crime was increasing by leaps and bounds in all sections of the country. In Cleveland in

the areas outside of the "White Way" district street crimes committed after dark increased 54 per cent over 1915, however crimes in the "White Way" district actually decreased 8 per cent in comparison with 1915. In other words, crimes in the business section of Cleveland in the year 1916 were only 60 per cent of what might well have been expected had no change been made in the lighting.

NORMAN MACBETH: I believe, as Mr. Porter brought out, that many accidents are caused by failing to locate the intersecting streets. I was in Toronto a few months after their resident street lighting was made a few years ago. Their automobile accidents had increased tremendously. This in my opinion was not due to lack of adequate lighting or glare. The illumination of the roadway was so apparently uniform and of a sufficient intensity to be effective. On the basis of our present discussion it was too good. When a driver saw a clear, well lighted street ahead, he just naturally speeded up, and the other driver on an intersecting street likewise saw his way clear for several blocks ahead; and if timed rightly these two cars just had to come together. Accidents could hardly be avoided, and because of this fact, local engineers were endeavoring to decide upon some simple, definite street intersecting mark,—a kind of multi-colored globe, the colors of which would be effective with the largest percentage of partially color blind drivers,—a danger signal and distinct street corner signal that would be reasonably effective.

Adequate street lighting, as it is understood to-day, will not in my opinion justify any guarantee as to the lessening of automobile accidents unless the street intersections are also definitely indicated.

E. L. ELLIOTT: I worked some little time a year ago on a very similar problem of protecting grade railroad crossings and came in contact with the signal engineers of the New York Central and New Haven road who probably have had as much experience in that line as anyone. The insufficiency of simply hanging up a red light is one of the problems; people get used to seeing a red light and do not take notice of it. The railroad authorities have never been able to win in court on the ground that a red light was displayed; the courts have always held that it is not a sufficient

warning. Of course, the objection to the ringing signal is evident. What the railroads want is not a simple light, or symbol, but an actual sign with the word "Stop" on it, such as a gateman holds up for you to read. The same thing applies to street crossings for the prevention of automobile accidents; some method of displaying a luminous sign with the word "Stop," "Dangerous," or whatever legend will best serve as a warning, would be much more effective than any mere colored light, or symbol.

L. C. PORTER: This seems to be a new subject. Mr. Elliott has brought out an interesting point and I would say on some of these signals which have been developed, flashing signals, there are words on them. If one sees a flashing red light one will stop, whereas, as has been pointed out, often one does not stop with a fixed light. Where the railroads are operating these signals at their grade crossings, they are operating them through relays so the signal starts to flash on the approach of a train and stops when the train has passed. At the street crossing or the highway crossing, the signal operates all the time, twenty-four hours a day.

E. A. ANDERSON: Several have discussed the use of danger signals to prevent traffic accidents, and I believe that it is generally accepted that such signals, flashing or otherwise, are extremely valuable in indicating those special danger points where the driver must proceed cautiously or come to a full stop. A most necessary function of good street illumination on thoroughfares, however, is to permit the traffic to move not only safetly but rapidly as well in order to avoid congestion. There is the further point that a too frequent use of danger signals tends to lead to indifference. As a matter of fact, therefore, a thoroughly satisfactory artificial lighting system for thoroughfares must provide for a fairly high level of general street illumination with an addition of danger signals for locations where unusual caution is required.

Mention was made of the desirability of a sign spelling out the word "S-T-O-P" or some equivalent as preferable to a red light for a danger signal. In Cleveland a lighted red cross mounted perhaps fifteen feet above the pavement is used to designate certain thoroughfare crossings and is quite effective. One of the oldest methods for signaling traffic is the use of a partly

red globe on the street lamp, in the attempt to have the street lamp serve the dual purpose of providing illumination and signaling danger. Experience has shown, however, that at any great distance the red band does not stand out, as the eye integrates the entire light source and the appearance of the globe is the equivalent of a slightly orange tone. It is apparently necessary to definitely separate the red signal lamp from the street lighting globe if the installation is to be fully successful.

As to the level of road illumination which is desirable for thoroughfares, there was an interesting point bearing on the subject in the paper by Messrs. Magdsick and Falge on desirable road illumination from automobile headlights.* The experiments reported in this paper indicated that the average driver desired at least two to three foot-candles at a distance two hundred feet in front of the car. If these values are accepted it would appear that in the future a minimum of three foot-candles will be considered necessary for street lighting of important thoroughfares and that is three to five times as much as the best lighting in most cities at present.

One speaker mentioned the importance of further development of lighting country highways. In this connection it would be noted that while in our investigation the average percentage of night accidents on city streets which can be attributed to lack of illumination was 17.6, a similar investigation applying to country highways, which are generally entirely without light at the present time, might show a figure as high as 50 per cent chargeable to lack of effective illumination.

There is a legal phase to this matter of street accidents due to ineffective illumination which has not been referred to specifically in the discussion. For many years municipalities have been held responsible for damages resulting from poorly constructed roadways or sidewalks and the losses from this cause have undoubtedly led to increased attention toward maintenance of roadways in many places.

A recent case in Cuyahoga County, Ohio, where the plaintiff entered suit against the city and county for many thousands of dollars for severe personal injuries in a street accident is notable

* Determination by Various Observers of the Desired Road Illumination from Automobile Headlamps. H. H. Magdsick and R. N. Falge. TRANSACTIONS I. E. S. Vol. XVI, No. 8, p. 480.

in that the plaintiff based his claim entirely on the fact that the size of lamps at the point where the accident occurred had been reduced from 300 to 100 watts, which he claimed did not afford sufficient illumination to reveal the road obstruction which was the immediate cause of the accident.

In closing I wish to acknowledge our great indebtedness to those organizations and individuals in the various cities who so kindly co-operated with us in tabulating the accident data for their individual cities. In fact the chief credit for such value as may attach to this survey really belongs to those whose interested co-operative efforts made possible the collection of the data.

O. F. HAAS: It is evident that there is a large field for danger signals in such locations as sharp curves, railroad crossings, etc., but, as Mr. Anderson remarked, such signals cannot be looked to for supplying safety protection for the same class of accidents as does a well designed street lighting installation.

A complete analysis of the causes of each accident occurring in one of the cities included in this survey indicates that by far the greater percentage of the accidents occurring on the city streets at night are of the following classes:

1. Automobile collisions or the crash by an automobile into parked or slow moving vehicles.

2. The running down of a "jay walker" or of a child by an automobile or street car.

3. Accidents occurring from depression in or obstructions on the sidewalk or pavement.

4. Pedestrians who are run down as they step in a dark area from the sidewalk on to the pavement to board a street car, or run down as they step from a street car into a dark area.

It is night accidents of these classes that can to a large extent be eliminated by supplying an effective street lighting installation, although the use of danger signals would not apply.

PRESENT STATUS OF AUTOMOBILE HEADLIGHTING REGULATION*

REPORT OF COMMITTEE ON MOTOR VEHICLE LIGHTING—1920-1921

It is gratifying to note that the regulation of automobile headlighting in accordance with the I. E. S. system has made considerable progress during the past year. In the last report the following states were given as having adopted it—New York, California, Pennsylvania, Connecticut, Maryland and Wisconsin. At the time of the last convention news was received that the Province of Ontario had also adopted the system. Since that time it has gone into use in the States of Nebraska, Utah, Iowa and Ohio, while Massachusetts has adopted the system in principle but has written somewhat different specifications for test, which may give very interesting results in practice.

Whereas in the last report it was noted that the states operating under this system registered approximately 25 per cent of all the cars in the country, the percentage now has risen to approximately 43, according to the latest figures published in Automotive Industries. The registration in the Province of Ontario constitutes about 42½ per cent of the total registration in the Dominion of Canada.

In view of the wide acceptance of the I. E. S. specifications, the Council of the Society, on recommendation of this Committee, voted that the Committee should on behalf of the Society submit these specifications to the American Engineering Standards Committee for adoption as a tentative American standard. This matter is still pending at the present time.

The rules and specifications of the committee for headlighting were submitted to the U. S. National Committee of the International Commission on Illumination and by that Committee were laid before a meeting of the International Commission on Illumination in Paris in July of this year. No word has as yet come to hand as to the amount of consideration given to this matter, but the minutes of the meeting at Paris are an evidence

*A report presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

that it attracted an attention which is proportional to its importance, because the International Commission on Illumination adopted the following resolution:

(6) Automobile Headlighting.

> The International Commission on Illumination records its strong opinion that regulations respecting limitations of the light from automobile headlamps should be framed with reference to international agreement so that the regulations may be uniform for all countries. With this object it desires each National Committee to keep in close touch with the authority in its own country which lays down rules for automobile headlighting.
>
> The Commission establishes a Committee of Study charged to study the problem of automobile headlighting, and to report to the next session of the Commission.
>
> The Committee shall consist of one member from each country nominated by the National Committee. The Committee shall be presided over by Dr. C. H. Sharp as President.
>
> The Commission delegates to the above Committee of Study the following duties:—
>
> (a) To endeavor to frame technical proposals which shall be suitable for international adoption.
>
> (b) To use the influence of the International Commission to secure in each country the recognition of the necessity for international standardization in this matter in order to avoid the establishment of a number of different sets of regulations throughout the world.

The work of the Committee during the past year has been largely in connection with details. The Committee has in mind, however, recommendation of one modification of procedure when special front glasses and similar devices are submitted for test. At the present time two pairs of a certain size are tested with both 15-cp. vacuum lamps and 21-cp. gas-filled lamps. It is proposed that the test shall be made with gas-filled lamps only, but with one pair of each of the four sizes which have been standardized by the Society of Automotive Engineers. These four sizes are: $8\,^5/_{32}$ inch, $8\frac{1}{2}$ inch, 9 inch and $9\frac{1}{2}$ inch. The object of the change is to make the results of the test more representative of the device, inasmuch as different moulds are used for these various sizes. Since the specifications are in use

in a number of States, it has seemed desirable first to communicate with the authorities of the states as to their willingness to agree to the change before actually adopting it.

A question has been raised as to the applicability of the I. E. S. specifications to acetylene headlamps, which are very widely used on motor cycles and on trucks. Admittedly the specifications have been drawn to cover the case of the electric headlamps, and whether they should be applied in their present form to the acetylene headlamps is at least a debatable question. The point having been raised by the Society of Automotive Engineers and also by the Motor Truck Association of America, and the International Acetylene Association, the Committee organized a joint meeting representative as far as possible of all those directly interested in the question. It developed from the discussion that there is a practical lack of fundamental data on the performance of acetylene headlamps, so that it was decided that the necessary information and data should be obtained under the direction of a small committee on which the various interests should be represented. Such a committee has been appointed with the Chairman of your Committee as its Chairman, and the collection of data is now under way. It is anticipated that an investigation by means of road tests will be necessary before the matter can be concluded.

From reports received it would appear that conditions on the road in night driving are becoming markedly better. Complaints, however, are still heard of excessively glaring light sources, and there has been a tendency at times for some to say that the work of the Committee is futile because it has not resulted in more radical improvement. The committee submits that such criticisms are not necessarily just. The work of the Committee extends only to a certain point; namely to the definition in numerical terms of the allowable limits of illumination and glare from headlamps on the road, and to the drawing of specifications whereby through laboratory tests the capability of various headlighting devices to conform to these limits may be determined. The laboratory test does not in any way show whether the actual performance on the road of any given device is within the requirements, or is not. This test simply shows that the device is capable of being adjusted and used in such a way that it will give

a performance which is within the requirements and what the proper adjustments are. Whether the device actually does so perform is dependent upon very many features entirly outside the control of the laboratory test. The matter of focusing and of aiming the lamps is of fundamental importance. Lamps incorrectly focused or aimed may even with the best of devices produce an intolerable glare or an abominable road illumination, or both. Hence while the laboratory test enables the user to select devices which are capable of conforming to requirements and tells him how they should be adjusted, and so is of the greatest value to him, yet in the last analysis it remains with the user to see that he gets the performance of which the device is capable. The matter is similar to that of horns and brakes; a badly adjusted horn will not make an adequate signal; nor will badly adjusted brakes bring the car to a stop within the limitations of safety. No one expects that the provision of a good horn or of good brakes on a car shall absolve the user of all responsibility for their adjustment and maintenance, neither is it to be expected that by fitting a suitable headlighting device to the car, a proper road illumination will be obtained unless it is adjusted as it individually should be. Suggested instructions for making these adjustments are given in the appendix to this report.

This fact is appreciated by all too few of the sellers and the users of such devices. Evidently therefore the results on the road are to a very great extent dependent upon the education of the motorist with respect to the proper adjustment of his headlamps and to the officers of the law to whom the enforcement of headlighting regulations is entrusted. With the education of the user and with the proper enforcement of the highway laws (which is all the time becoming more rigid and more intelligent) it can be expected that the conditions for road illumination laid down by the Illuminating Engineering Society as being suitable, will be conformed to by a larger and larger percentage of automobilists. It is to the credit of this Society that it has formulated a definite standard and has indicated what now seems to be the only practicable road leading to a reform of the abuses connected with motor vehicle headlighting.

The Committee has never taken up the question of proper standards for the illumination of rear license plates on motor

cars. The determination of such a standard is complicated by the variations introduced by the variation in color and surface of the plates themselves and by the possible glare from the red tail lamps. Furthermore stop and turn signals are coming into use, depending on artificial lighting. For these also standards are needed. There is real need for an authoritative booklet on the proper adjustment of headlamps and on simple methods of checking the illumination to see if it conforms to specifications. Evidently your committee to be appointed for the ensuing year cannot lack for fruitful fields in which to labor.

COMMITTEE ON MOTOR VEHICLE LIGHTING

G. N. CHAMBERLIN
P. W. COBB
E. C. CRITTENDEN
J. A. HOEVELER
W. F. LITTLE
W. A. MCKAY
*A. L. MCMURTRY
**H. H. MAGDSICK
L. C. PORTER
G. H. STICKNEY
L. E. VOYER

CLAYTON H. SHARP, *Chairman.*

*Mr. McMurtry has filed an objection to the publication of the appendix as part of the official Report of the Committee.

**Mr. Magdsick has proposed certain additions to the Report which through lack of time the Committee has not been able to consider.

REPORT OF COMMITTEE ON MOTOR VEHICLE LIGHTING

APPENDIX

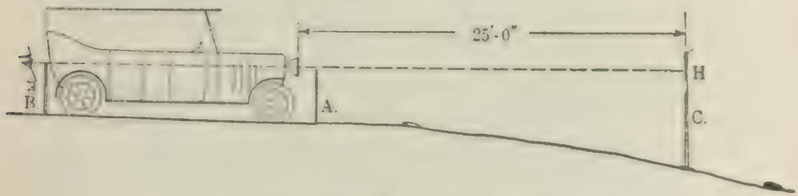
INSTRUCTIONS FOR THE PROPER ADJUSTMENT OF AUTOMOBILE HEADLAMPS TO CONFORMITY WITH THE RULES OF THE ILLUMINATING ENGINEERING SOCIETY

Headlighting devices which have been tested and approved under the specifications of the I. E. S. for laboratory tests of such devices are thereby shown to be capable of giving, under certain stated conditions, the type of road illumination required in the I. E. S. rules. Unless these conditions, which include the rating of the incandescent lamps used, the tilt of the headlamps and the focusing, are strictly complied with, the illumination results are liable to be entirely wrong and unsatisfactory both to the user and to others on the road.

Purpose of Headlight Controlling Device.—Controlling devices are for the purpose of securing an adequate road illumination without a dangerous glare in the eyes of other users of the road. This is accomplished by deflecting the major part of the beam toward the road surface, leaving the upper portion of the beam of low enough intensity to avoid dangerous glare, while still allowing enough light in this upper region to enable the driver to proceed with safety. Not only should the light be directed toward the road, but it should be spread sidewise in order that a sufficient portion of the road surface is rendered visible to avoid danger of striking a person or object thereon. Efficient controlling devices improve the road illumination for the user of the device and at the same time create conditions such that other users of the road are not put in jeopardy by glare. However such devices require a careful adjustment of the incandescent lamp in the focus of the reflector and sometimes a downward tilt of the headlamps in order that the above result may be accomplished, and without careful adjustment in these particulars the use of the pair of controlling devices may result in bad road illumination and excessive glare, their purpose being entirely defeated.

Incandescent Lamps.—Incandescent lamps or bulbs at present on the market are of two types: the vacuum or type B lamp and the gas-filled or type C lamp. The filament of the type B lamp is arranged in the form of a small horizontal coil. The filament of the type C lamp is in the form of a "V," which "V" is made up of a minute spiral of wire. On account of the different shapes of the filaments of type B and type C lamps, in many cases a higher candle-power can be used with one type than with other, without exceeding the specified limits of glare. See that the marked candlepower of your lamps is not greater than that allowed with the device you propose using, and that the filaments are well centered in the bulbs.

Adjustment of Tilt.—Place the car fully loaded on a level surface, as for instance, the floor of the garage (see accompanying figure). Measure the height of the center of the headlamps from the floor, and cut off two sticks to a length equal to this height. Stand one of the sticks, A, near the front end of the car and the other, B, near the rear. Arrange a board, C, so that it will stand on end, and set this up as a target at a distance of 25 ft. ahead of the lamps so that the light of one headlamp or of both shines upon it. Remove the front glass from the lamp, or use only the plain glass, and operate the focusing adjustment (see below) so that the light forms a small patch on the target. Sight over the top of the two vertical markers, A and B, on to the target, C, and place a line, H, at the point thus found. This



Arrangement for adjusting the tilt.

will give the horizontal line. If the height of the center of the beam comes at the same height as this mark, the beam is horizontal. If the device which is to be used is one requiring a tilted beam, put another mark on the target at the requisite distance below the first mark. For instance, if a tilt of 2 ft. in 100 is required, the target being 25 ft. ahead of the lamps, the

mark should be placed 6 in. below the horizontal mark. The headlamp is then tilted until the center of the beam comes at this lower mark with the car fully loaded. By shifting the target the other lamp can be similarly adjusted. The actual tilting of the headlamps is a mechanical adjustment which in some makes of cars is very simple and in others requires some mechanical skill. See that the beams of both lamps point straight ahead. The horizontal distance between the centres of the beams should equal the distance between the centres of the headlamps.

Focus Adjustment.—All, or nearly all headlamps are provided with an arrangement whereby the position of the bulb may be changed with respect to the focus of the parabolic mirror. This arrangement is sometimes a little difficult to find, but any owner who is in trouble from this cause may well consult a competent garage man. The adjustment of focus, as well as of tilt, can best be accomplished in moderate darkness. It will be found that taking the headlamps without any controlling devices whatever, and throwing the beam from each one separately on to the target, a more or less round spot or patch of light is seen.

By operating the focusing adjustment the lamp is moved backward or forward with respect to the reflector. The following adjustments are recognized. Some devices require one of these adjustments, others another.

Adjustment No. 1.—The center of the lamp filament is at the focus of the reflector. The patch of light made by the beam is then of minimum diameter.

Adjustment No. 2.—The lamp is drawn backward from No. 1 adjustment. When this is done the patch of light becomes larger and finally a black spot appears at its center. When this spot is just on the point of appearing, adjustment No. 2 has been made.

Adjustment No. 3.—The lamp position is intermediate between No. 1 and No. 2. The size of the patch of light is intermediate between No. 1 and No. 2.

Adjustment No. 4.—The lamp is pushed forward from position No. 1 until a black spot is on the point of forming in the center of the patch of light.

In case the headlamp is so constructed that it is not easy to tell whether one is moving the lamp forward or backward, No. 2 can be distinguished from No. 4 by blowing a cloud of smoke into the beam directly in front of the headlamp. If the rays of light are seen to diverge as they leave the reflector, the adjustment is No. 2; if they converge and cross, it is No. 4.

Be sure that the lamps are positively locked in position after the adjustment has been made. Some types of headlamps are so constructed that the focal adjustment is altered on replacing the front glass. With these headlamps the correctness of the adjustment can be judged by inspecting the patch of light thrown with the device in place. The top of the patch should be cut off more or less horizontally across the top and the major portion of the patch should be below the horizontal line.

Beam Adjustment.—Having secured the right tilt and focus adjustment, the controlling device which it is proposed to use is affixed to the headlamps, care being taken to see that it is placed exactly in accordance with the manufacturer's instructions, which should accompany the device. The beam is then once more observed on the target to see whether the upper half of the beam is properly cut off and the light deflected toward the road. In the case of many devices this cut-off is secured with the bulb at the reflector focus. In the case of some, however (those which obstruct the light from the upper part of the headlamp), the bulb must be brought back toward the reflector in order to secure this cut-off, (Adjustment No. 2.)—With still others (those which obstruct the light from the lower half of the reflector) the bulb must be pushed forward ahead of the focus, (Adjustment No. 4).—In any case a little experimenting will show what adjustment is necessary in order to secure the sharpest possible cut-off of the upper half of the beam.

Improvised Devices.—There are several ways in which a substantial compliance with the rules may be insured without purchasing special controlling devices. Among these may be noted the following:

Covering the upper half of the front with a dense diffusing coating or with white paper, and adjusting the bulb back of the focus, as describing above, makes a fairly good expedient.

Covering the upper half of the bulb with a semiopaque substance and adjusting the focus as above, accomplishes a similar result. There are other methods which may be employed, but probably none of them will give as good a result as the use of a good commercial device designed for the purpose.

Maintenance of Headlamps.—Dust and dirt on front glasses and reflectors cut down the efficiency of headlamps very greatly. Therefore periodic cleaning should be resorted to. Old and blackened lamp bulbs give greatly diminished candlepower and should be renewed. Bad wiring switches and sockets and rundown batteries are frequently causes of a similar result.

RULES FOR PHOTOMETRIC INSPECTION OF HEADLAMPS ON MOTOR VEHICLES AND MOTOR CYCLES

In order to determine whether the headlighting of a motor vehicle or motor cycle conforms to the requirements of the law, it may be subjected to photometric inspection as follows:

Without change in any adjustment of the headlamps, the car shall be placed, fully loaded, upon a level surface in a location suitable for making photometric measurements. The engine shall be operated at a speed corresponding to 25 miles per hour when in high gear.

The horizontal line of the headlamps 100 ft. ahead of the vehicle shall be established by sighting, as described under "Adjustment of Tilt."

The photometric measurements shall be made with a foot-candle meter or an equivalent measuring device.

Measurements shall be made at the following positions at a distance of 100 ft. ahead of the headlamps:

Position 1.—Directly ahead and at a height not less than one-half the distance of the center of the headlamps above the level surface. The indication of the foot-candle meter shall be not less than 0.48 ft-c. for a motor vehicle and not less than 0.24 ft-c. for a motor cycle.

Position 2.—Seven feet to the right of Position 1 at any point not above the level of the headlamps. The indication of the foot-candle meter shall be not less than 0.12 ft-c. for a motor vehicle and not less than 0.06 ft-c. for a motor cycle.

Position 3.—Directly in front, 5 ft. above the level surface. The indication of the foot-candle meter shall be not more than 0.24 ft-c.

Position 4.—Five feet above the level surface and 7 ft. to the left of the axis of the vehicle. The indication of the foot-candle meter shall be not more than 0.08 ft-c.

Note—In order to allow for any possible inaccuracies of a test of this character, a tolerance of 20 per cent may be allowed on the above values.

DISCUSSION

The Report of the Committee on Motor Vehicle Lighting and the papers by Messrs. Madgsick and Falge and Mr. Devine were discussed together. See page 518

DETERMINATION BY VARIOUS OBSERVERS OF THE DESIRED ROAD ILLUMINATION FROM AUTOMOBILE HEADLAMPS*

H. H. MAGDSICK AND R. N. FALGE**

SYNOPSIS: There are presented data showing the road illumination from headlighting equipment as set in a moving car by a total of thirteen observers, under various conditions of road surface, contour, boundaries, streetlighting, weather, speeds, etc., with lighting facilities which offered a considerable range of intensity and distribution. These data indicate in a general way the lighting required for safety and a moderate degree of convenience, that is, the lower limit of what might be termed good practice, for the more common road conditions. They are not sufficiently complete to permit an analysis of the effect of each of the variable factors. A description is given of the equipment employed together with an outline of the procedure followed in obtaining the data.

In order to supplement the existing meager quantitative information as to the requirements of road illumination from motor cars, facilities as described below were developed with which an observer might obtain a considerable degree of control of both distribution and intensity of light, and thus adjust the lighting to meet the requirements of particular roads under the conditions of actual use.

Among the factors which affect the road illumination requirements, are the following:

1—Character of the road surface as to reflection factor, smoothness, presence of obstacles or holes, and width.

2—Character of the road boundaries as to ditches, cuts, weeds, shrubs and trees, fences, telephone poles, signs, etc.

3—Contour of the road—grades, curves, turns, etc.

4—Lighting of the road from street lamps, other vehicles, and moonlight; glare from approaching headlamps.

5—Atmospheric conditions.

6—Traffic, both vehicle and pedestrian.

7—Speed.

8—Variations among drivers as to vision, driving habits, temperament, etc.

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**Engineering Department, National Lamp Works of General Electric Co., Cleveland, Ohio.

An investigation which would cover in a comprehensive manner all of these variables and the effects of each was not attempted. The endeavor was to obtain an approximation of the road lighting which would prove adequate under the more usual conditions.

To cover representative road conditions determinations were made on the following:

(a) Country highways having 14-foot red brick pavement with either dirt or grass strip; grass and shallow ditches to fences, with and without trees; level, rolling and straight stretches, wide and sharp curves, a few deep holes, railroad crossings and short bridges; unlighted; used when dry and clean, dry with light dust, wet and with snow.

(b) Suburban highways with 24-foot red brick pavement; grass and weeds to sidewalks or fences; part with light curb stones; level and easy grades, moderate curves; poor street lighting with widely spaced units; used dry and wet with snow.

(c) Suburban highway with 30-foot red brick pavement and light curb stones; grass and weeds to fences, few trees; straight and level; poor street lighting.

(d) Crushed stone country road with somewhat irregular surface; weeds and ditches to fences, many trees; winding and rolling; no lighting.

(e) Outlying park road with 24-foot dark tarvia pavement and light curb stones; lawns and trees at sides; winding and somewhat rolling; dark cross roads and dead end; no lighting; used dry and wet.

(f) City thoroughfare with 50-foot dark asphalt paving, street railway tracks; grass strips to sidewalks; straight and level; fair lighting.

Atmospheric conditions were for the most part clear with occasional hazy low areas. In the case of a few determinations there was a light general mist. In the case of tests on wet and partially snow-covered roads there was some interference with vision resulting from drops of water on the windshield.

Traffic varied on the roads from time to time. In most cases lighted cars were met during the determinations for each class of road, but in no case were settings made for the condition of a

considerable stretch of road lighted by other cars. Pedestrians were usually encountered on the pavement, and occasionally a vehicle without lights.

Of the thirteen men who acted as observers, all but two are experienced car drivers. They vary considerably in temperament and in driving habits; they live in various states of the east and and central west. Several have for years been careful students of motor car lighting; for the most part they are trained observers and all but one have some connection with the lighting industry. One is a state official responsible for headlight regulation; two have a commercial interest in certain headlighting equipments. Only a few had ever before been over the roads traversed in the tests. The authors' determinations are not included in this paper. No tests were made of the vision of the several observers, although from this standpoint they are believed to be a representative lot of men.

The car used in the tests is shown in Fig. 3. Provision is made for mounting six headlamps, each swiveled and adjustable also for height and tilt. The four units on the forward bar may be tilted simultaneously through a desired angle by means of the graduated member fastened to the radiator cap. Adjustable sockets give further flexibilty. Control of the beam is secured by means of various cover glasses of the familiar types as well as with a number specially cut with vertical flutes to spread the light in various proportions and degrees. Further control of the light distribution is obtained by the use of masks intercepting parts of the beam; thus the highest intensity is found at the top of the beam when one-half of the usual paraboloidal unit is masked and the light source placed out of focus or a narrow beam with the maximum candle-power at the center results when the source is at the focus and the light is intercepted from the central part of the reflector, where the beam divergence is greatest.

Energy for the lamps of 6-8 volt rating is supplied from a 4-cell lead storage battery not connected with the electrical system of the car. A bank of rheostats is provided under the cowl and these are arranged for connection in any of the lamp circuits. The circuits are completed through two-way knife switches also mounted under the cowl and the wiring is so arranged that by means of a push-button switch one may change instantly from one

Fig. 1—Some of the roads used for the tests

Fig. 2.—One of the roads used for the tests.

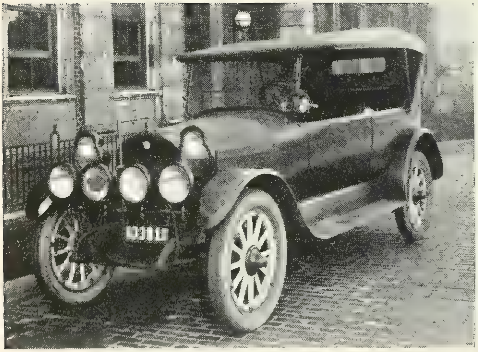

Fig. 3

Fig. 4

Fig. 3.—The test car showing the mounting of the six headlamps.

Fig. 4.—The cowl of the test car showing arrangement of bank of rheostats, control switches and ammeter.

set of lighting units to another. A portable laboratory ammeter is mounted on a bracket from the cowl and by means of the two-way switches one may measure the current through a given lamp while the others employed remain burning, and thus determine the actual current taken by the several lamps in a given setting of the units.

In obtaining the data included in this paper the observer usually sat in the front seat at the side of the driver where he could readily manipulate the switches and rheostats; in a few cases the observer drove the car. Four lighting units were mounted on the forward bar with their centers at a height of 37 inches from the ground. The height of the lamps on a motor car, varying from 32 to 42 inches, is limited by considerations of body design to levels somewhat below those that experience shows to result in the best illumination. The height of 37 inches was taken as typical of practice. By means of the various cover glasses, and tilting and socket adjustments, the distribution of the light on the road was built up to meet the desires of the observer. This usually resulted in three or four overlapping beams directed one before the other down the road with the lateral angular spread increasing toward the car. Two restrictions placed upon the observer were, first, that the intensity of the light directed to the "glare" points "C" and "D" of the specification of the Committee on Motor Vehicle Lighting were limited within the maximum values there specified; second, that no provision was made for asymmetrical sidewise distribution—the right and left halves of the beam from each unit were substantially the same.

The observer was requested to set the illumination for the different parts of the road and boundaries at the lowest values which would satisfy him from the standpoints of safety and afford a reasonable degree of convenience in operating the car. These instructions may seem rather indefinite but in practice they appeared to be followed easily by the observers who, as a rule, had little difficulty in quickly forming their judgments. It should be noted that unless restricted in this manner the lighting chosen was of a considerably higher order in intensity and of wider spread. The data shown below should, therefore, be considered as representing the lower limits of good practice for the conditions indicated.

Before proceeding to make recorded determinations, the observer was driven over various roads while he adjusted the beam by means of the rheostats and was then given an opportunity to change the cover glasses, the relative tilt of the several units or the tilt of the bank of lamps, or otherwise to modify the beam. With any such desired changes made, the procedure was to drive over roads of one of the classifications given above at speeds up to 25 miles per hour, holding fairly closely to the upper value, and to allow the observer to vary the intensity of the several units until he had satisfied himself as to what he considered desirable lighting, The current through each of the lamps was then read and recorded and the rheostat slides pushed down till the lighting was entirely inadequate, when the next determination was made.

Similar data were obtained, although not with all observers, for speeds up to 40 miles per hour; the settings were made to provide sufficient illumination for holding this upper value. Experience had shown that for most conditions the need for further light above the horizontal became rapidly more urgent at speeds above 25 miles per hour in order that the road might be revealed far enough ahead to proceed safety at such speeds. For the data at the higher speeds, therefore, the observer was allowed to disregard the matter of glare and to add such light as he desired above the horizontal, being required only to turn out this part of the beam for an approaching vehicle or pedestrian.

The car was finally driven into the laboratory where the distribution of light was measured from each unit without disturbing its adjustment. Measurements were made with a portable photometer at a distance of 80 feet from the headlamps. The beams from the several units were referred to one vertical axis, so that in effect the recorded data do not apply strictly for the units as used, but rather for a single unit combining the several beams. With the lamp current of each unit recorded for the different settings, the combined beams could then be calculated. For convenience in recording and analyzing, the results were plotted as lines of equal candle-power in a vertical plane so far ahead of the car, say 100 feet, that the beam may be considered as coming from a single source, as illustrated by Fig. 8. One may consider such

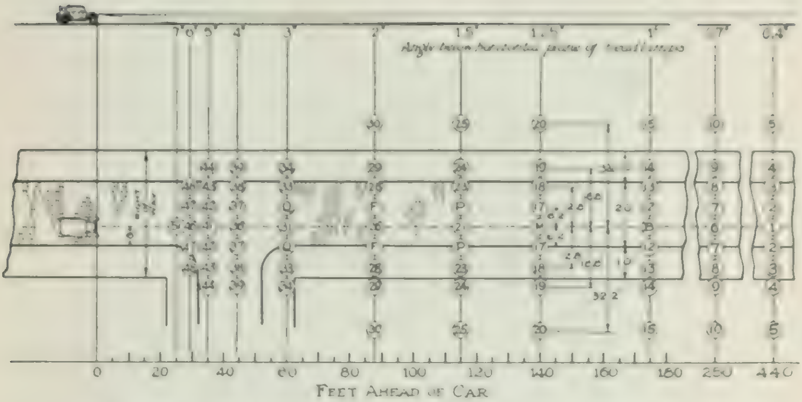

Fig. 5.—Location of stations at road level for which candlepower data are given in the tables.

Note—B and F are projections on road surface of points in I. E. S. specifications. M, P and Q are projections on road surface of points in Massachusetts regulations.

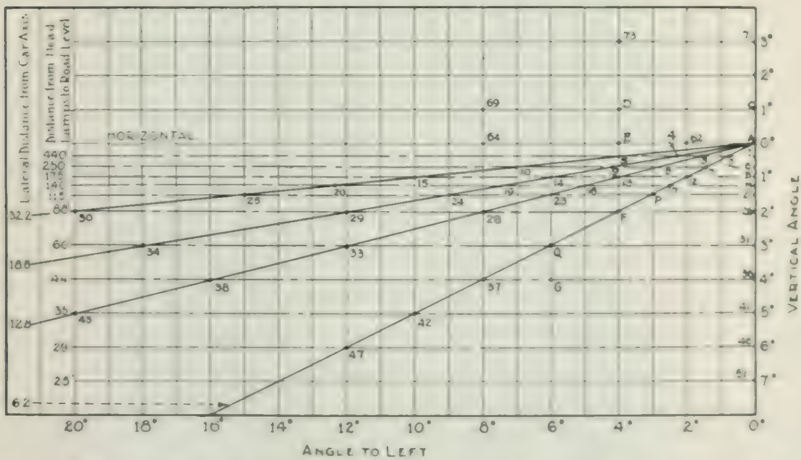

Fig. 6.—Location of stations to left of car axis as viewed in perspective from between headlamps for which candlepower data are given in the tables.

Note—Points A, B, C, D, E and F are from I. E. S. specifications. Points M, P and Q are from Massachussetts regulations.

Fig. 7.—View of road with 30-foot pavement showing approximate location of stations as viewed from headlamps.

a plot as representing the illuminated field in this plane with the brightness of the various parts proportional to the numerical values on the several lines.

Instead of showing the complete results for each determination, there are included in Tables 1 to 14 the maximum, average, and minimum candle-power values for each road condition at certain points selected to cover the various things it might be helpful to see in driving along an unfamiliar road. The location of these points is given in the diagrams of Fig. 5 and 6 and is further illustrated on the road of Fig. 7. The values of "average candle-power for all observers" give equal weight to each person; that is, if an observer made more than one determination for a given road condition, the average of these was taken as his setting.

The average candle-power values of Table 4 are found expressed in Table 16 as corresponding values of illumination on a surface normal to the beam and at the road level for the same stations. This one table suffices to indicate the order of the illumination and the variation at the different distances ahead of the car.

Unfortunately some of the observers were not available for a sufficient time to make determinations for all of the road conditions; those for whom data were obtained on wet roads were, for example not available when the roads were dry. The data are therefore not so complete and so well adapted for comparison as would be desirable.

In some of the earlier tests, means were not provided for bringing the highest intensity close to the top of the beam and hence the observers had no opportunity to choose this form of distribution. The later data obtained when such facilities were afforded indicate that the highest intensity would in the average case have been set for angles closer to the horizontal, in other words, projected farther down the road. This fact should be kept in mind in looking over the Tables and curves that follow. At the same time it should be noted that whenever equipment giving a high intensity at the top of the beam was employed, it was always set with the beam directed from 1 to 1½ degrees below the limiting height at which it could be directed and still comply with the I. E. S. specifications for the "C" and "D" points. With

this type of beam the I. E. S. specifications are not adequate to prevent an adjustment resulting in undue interference with the vision of the approaching driver because of a rapid succession of glaring flashes when the car is in motion, even on a fairly smooth road.

In one particular the data as shown may not apply for the points indicated. The car employed is driven through the springs, and with this form of drive it was found that there is some deflection of the springs, aside from that caused by the loading of the car, which varies with the pull exerted. The actual upward tilt of the light beams occasioned in this manner has not been determined exactly, but it appears that it may in some cases amount to as much as from ¼ to½ degree. It varies greatly in driving due to changes in the pull exerted, the effect of bumps, etc., and for this reason no correction was attempted for this factor. Correction was, however, made for the difference in the loading of the car during the determinations and in the laboratory.

In Table 15 the average candle-power values for the six road conditions are assembled for ready comparison. One might possibly expect to find the desired illumination varying inversely with the reflection factor of the road surface but the data do not show such results. It appears that the illumination on surfaces such as light curb stones, weeds trees,fences, etc., at the sides of the road tended to define it sufficiently to make a relatively lower brightness of the road surface itself satisfactory in the case of the darker roads.

On wet pavements the desired illumination increased both because of the greater specular reflection, directing the light away from the car, and the greater distances needed for bringing the car to a stop on the slippery surface. More particularly was the higher intensity demanded near the top of the beam, which light strikes the road surface at more nearly the grazing angle. On smooth, level pavements it was noticed that the effect of the specular reflection was to redirect light forward to signs, fences, trees and other vertical surfaces and thus reveal the road so far ahead as to make the need for light above the horizontal less urgent at higher speeds. On the other hand, under other road and boundary conditions the need for increased light above the

horizontal became urgent at materially lower speeds than with the dry road.

From Table 4 it appears that the greater speed of vision required at the higher car speeds is reflected in the desire for higher intensities not only far down the road but also somewhat closer to the car.

The beams indicated by these tests probably are not sufficiently wide to be satisfactory under certain road conditions not included in the determinations. At any rate, while the authors' settings gave results of the same order as those of the recorded observers on the roads selected for the tests, they found a wider spread, particularly at the bottom of the beam, of distinct value on some narrow dirt roads, hilly and sharply winding, with ditches on either side. On the other hand, some of the observers were most positive in their objection to a very wide beam because of the distraction caused by the relatively bright vertical surfaces of grass, weeds, etc., at the side of the road. On the dirt roads of the character above indicated, the need for greater light above the horizontal became imperative for safe driving at speeds well below 25 miles per hour; without it one was often limited to not over 15 miles per hour.

There was light from a half moon on the evening when one of the observers made his determinations. His settings were of the same order as those made by others without moonlight. Taken out on a dark evening, he set values somewhat lower except at the higher speeds. Moonlight reduces considerably the need for additional light from the headlamps, at and above the horizontal for driving at high speeds. It appears that what is desired by the driver is an idea of where the road goes to, so that he may be prepared for dead ends, sharp turns, crossings, signs, pedestrians, or any large obstructions. All of the experiences seem to indicate that the illumination of the vertical surfaces adjacent to the road bed in the distance is one of the chief requirements from the upward light.

Poor street lighting seemed not to decrease the illumination desired from the headlamps but rather to increase it slightly; with better street lighting the intensity set at points far ahead of the car was appreciably reduced. Street lamps serve very well

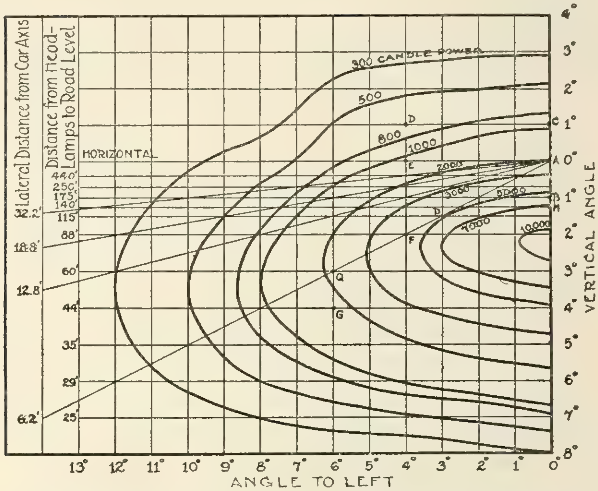

Fig. 8—Cross-section of average beam for 14 foot red brick paved country highways, dry, for car speed of 25 miles per hour (see Table 1). Lines of equal candlepower in vertical plane so far ahead of car, say 100 feet, that beam may be considered as coming from a single source.

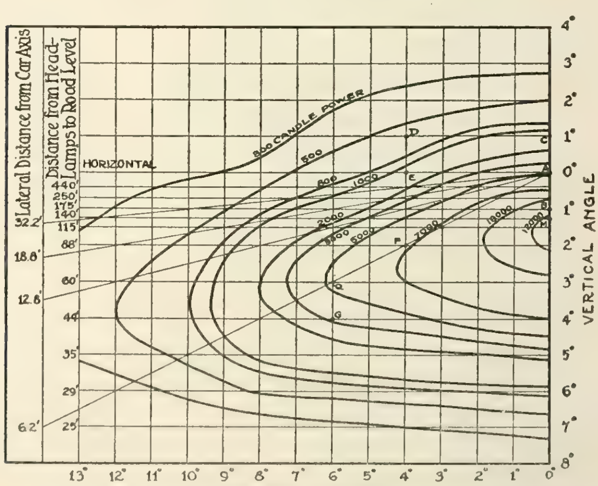

Fig. 9—Cross-section of average beam for 14 foot red brick paved country highways, wet, for car speed of 25 miles per hour (see Table 2). Lines of equal candlepower in vertical plane so far ahead of car, say 100 feet, that beam may be considered as coming from a single source.

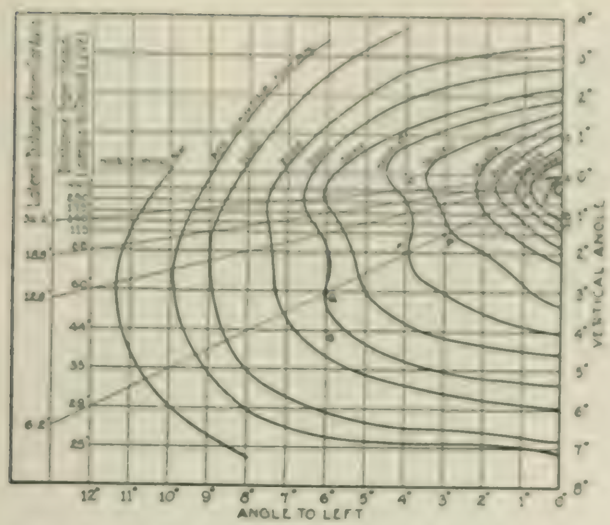

Fig. [illegible].—Cross-section of average beam for [illegible] foot red brick paved country highways, wet, for car speed of [illegible] miles per hour (see Table [illegible]). Lines of equal candlepower in vertical plane so far ahead of car, say [illegible] feet, that beam may be considered as coming from a single source.

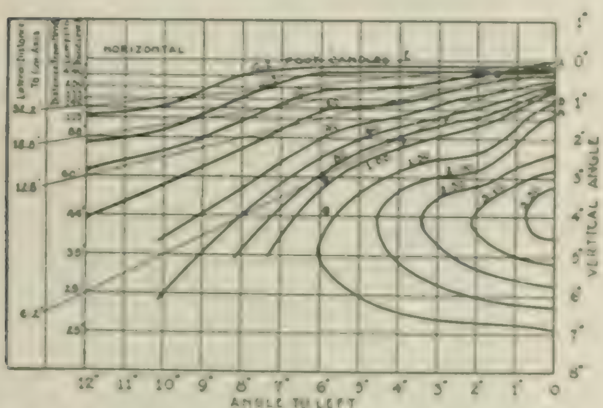

Fig. [illegible].—Lines of equal normal illumination at road level from average determination for [illegible] foot red brick paved country highways, dry, and car speed of [illegible] miles per hour (see Table [illegible]).

to indicate where the road leads and thus tends to make high intensities at and above the horizontal unnecessary even for high speeds.

Smoothness of beam, that is, freedom from streaks or striations, was found to have considerable effect in facilitating the determinations and appeared to reduce the total amount of light desired.

In Figs. 8, 9, and 10, some of the typical data are shown plotted as lines of equal candle-power in a vertical plane 100 feet ahead of the car. The data of Fig. 10 are translated in Fig. 11 into lines of equal illumination for surfaces normal to the beam at the road level. Fig. 9 covers the road condition for which the greatest illumination was demanded. It should be noted that the curves represent the average of the determinations for several observers; in determining what would constitute good practice one would doubtless wish to give some weight to the desires of the observers who, because of abnormal vision, temperament, or other reasons, desired lighting from 20 to 100 per cent higher in intensity, as shown in the Tables.

In considering any data of this kind from the standpoint of lighting equipment for a car, it must further be borne in mind that because of conditions beyond the control of the car owner, such as large variations in voltage at the lamp, departures from a perfect product in sockets, incandescent lamps, reflectors, and cover glasses, and depreciation in some of these elements, the laboratory tests with selected equipment must in general show twice the intensity values which it is desired to insure that the car owner obtain at all times in service.

The data presented are, as stated above, what the observers considered the minimum desirable from the standpoints of safety and reasonable convenience in driving under the given conditions. A higher order of intensity was in every case considered to reduce the strain of night driving and contribute to the safety and enjoyment of the driver and his passengers, while also minimizing the danger to the other people on the road.

TABLE I

Country Highways
Dry
Speed—25 miles per hour
Observers—8*

14-Foot Red Brick Pavement
No Street Lighting

Determinations—19

POINTS AT ROAD LEVEL

Distance ahead of car Angle below horizontal	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	[illegible] 0.5°
Station (32.2′ to side)						30	25	20	15	10	5
Max. cp. setting	...	...	...	...	...	460	670	780	820	[illegible]	[illegible]
Ave. cp. for all observers	...	...	...	...	...	110	215	[illegible]	[illegible]	710	1660
Min. cp. setting	...	...	...	...	...	25	50	50	75	170	[illegible]
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Max. cp. setting	...	...	110	135	260	670	970	1500	2410	[illegible]	[illegible]
Ave. cp. for all observers	...	...	45	60	100	250	580	830	1180	1870	2310
Min. cp. setting	...	...	10	20	30	60	110	165	300	740	1400
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Max. cp. setting	...	85	125	200	545	1320	3200	4800	5500	5600	4500
Ave. cp. for all observers	...	40	60	105	265	815	1600	2160	2640	2990	2840
Min. cp. setting	...	20	20	35	60	190	360	680	1240	1670	1780
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Max. cp. setting	...	645	1320	2000	4490	7700	11000	9900	8000	6000	4700
Ave. cp. for all observers	...	215	395	960	2120	[illegible]	5160	5200	4430	3890	3090
Min. cp. setting	...	55	80	200	625	1960	2500	2900	2660	2400	1980
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Max. cp. setting	2160	3730	3900	7250	12500	18860	12500	12200	10000	7000	5200
Ave. cp. for all observers	700	1700	2590	4950	8750	[illegible]	[illegible]	[illegible]	5750	4320	3060
Min. cp. setting	320	570	1310	3000	4350	5000	3950	3000	2350	1860	1440

POINTS ABOVE ROAD LEVEL

Angle above horizontal Angles left and right	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°
Station Number	A	62	E	64	65	C	D	69	71	73
Max. cp. setting	[illegible]	[illegible]	[illegible]	810	[illegible]	[illegible]	1710	[illegible]	[illegible]	[illegible]
Ave. cp. for all observers	[illegible]	[illegible]	[illegible]	[illegible]	170	[illegible]	685	[illegible]	270	[illegible]
Min. cp. setting	945	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115	115

*Light from half moon for determinations of one observer.

TABLE 2

Country Highways
Wet
Speed—25 miles per hour
Observers—3*

14-Foot Red Brick Pavement
No Street Lighting

Determinations—4

POINTS AT ROAD LEVEL

Distance ahead of car... Angle below horizontal.	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)...						30	25	20	15	10	5
Max. cp. setting.......	.....	.....	.....	.....	.....	335	400	500	670	900	3150
Ave. cp. for all observers.	.....	.....	.....	.....	.....	215	257	327	434	613	1917
Min. cp. setting........	.....	.....	.....	.....	.....	30	60	70	92	140	700
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Max. cp. setting.......	.....	.....	220	300	425	560	900	1400	2010	4000	6200
Ave. cp. for all observers	.....	.....	154	197	280	388	652	917	1315	2533	3742
Min. cp. setting........	.....	.....	23	22	35	55	155	150	334	800	2125
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Max. cp. setting.......	.....	170	300	460	620	2100	3500	4600	6010	7000	8000
Ave. cp. for all observers	.....	104	207	309	432	1447	2347	3317	3973	4075	5558
Min. cp. setting........	.....	23	30	39	55	212	390	750	1210	2225	4200
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Max. cp. setting.......	.....	290	900	3300	10400	11700	10000	10100	11400	9800	8800
Ave. cp. for all observers	.....	195	560	1733	5308	6852	7010	7800	7990	7550	6200
Min. cp. setting........	.....	46	106	315	565	1505	2330	3300	4585	6250	4650
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Max. cp. setting.......	700	1350	3500	11000	16000	16600	14900	13400	13000	12000	9500
Ave. cp. for all observers	384	900	2209	7020	9333	12095	12467	12117	11500	9150	6750
Min. cp. setting........	205	550	1099	3840	4040	6885	8900	9950	10500	7500	5000

POINTS ABOVE ROAD LEVEL

Angle above horizontal. Angles right and left....	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Max. cp. setting.......	6950	5030	1865	470	350	1670	735	337	302	300	
Ave. cp. for all observers	4416	2778	1206	343	234	1167	563	245	230	228	
Min. cp. setting........	2997	1205	405	118	52	830	255	97	168	116	

*Drizzling rain and slight mist for one observer.

TABLE 3

Country Highways
Dry*—Wet—Snow**
Speed—25 miles per hour
Observers—11
(8 dry, 3 wet, 2 snow)

14-Foot Red Brick Pavement
No Street Lighting

Determinations—24
(19 dry, 3 wet, 2 snow)

POINTS AT ROAD LEVEL

Distance ahead of car Angle below horizontal	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Ave. cp. for dry surface	.	..	...	.	...	110	215	256	365	710	1660
Ave. cp. for wet surface	.	..	...	.	.	215	257	327	444	613	1917
Ave. cp. for snow covered	.	.	...	...	...	84	85	100	165	270	825
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Ave. cp. for dry surface	.	...	45	60	100	250	580	830	1180	1870	2310
Ave. cp. for wet surface	.	...	154	197	280	388	652	917	1316	2533	3742
Ave. cp. for snow covered	.	.	40	62	108	130	308	393	593	943	1690
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Ave. cp. for dry surface	.	40	60	105	265	815	1600	2160	2640	2990	2840
Ave. cp. for wet surface	.	104	207	309	432	1447	2347	3317	3973	4075	5558
Ave. cp. for snow covered	.	34	55	110	155	532	913	838	1525	1955	2108
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Ave. cp. for dry surface	.	215	395	960	2120	4140	5160	5200	4430	3890	3090
Ave. cp. for wet surface		195	560	1733	5308	6852	7010	7800	10320	7550	6200
Ave. cp. for snow covered		54	179	451	1469	2513	2975	3463	3443	2688	2245
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Ave. cp. for dry surface	700	1700	2590	4950	8750	10500	8400	7200	5750	4320	3060
Ave. cp. for wet surface	384	900	2209	7020	9332	12695	12467	12117	11500	9450	6750
Ave. cp. for snow covered	204	414	1051	2203	5675	11405	7250	5250	4015	3150	2550

POINTS ABOVE ROAD LEVEL

Angle above horizontal Angles left and right	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Ave. cp. for dry surface	2070	1730	1075	380	170	930	685	265	270	235	
Ave. cp. for wet surface	4416	2778	1206	343	234	1167	563	244	236	224	
Ave. cp. for snow covered	1599	1188	490	166	88	581	314	109	149	152	

*From Table 1 **From Table 2

TABLE 4

Country Highways
Dry
Speed—40 miles per hour
Observers—6

14-Foot Red Brick Pavement
No Street Lighting

Determinations—11

POINTS AT ROAD LEVEL

Distance ahead of car...	25′	29′	35′	44′	60′	88′	115′	140′	175′	250′	440′
Angle below horizontal.	7°	6°	5°	4°	3°	2°	1.5°	1.25°	1°	0.7°	0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Max. cp. setting.......	.....	.....	.....	.....	.....	.....	.....	750	2008	5200	32500
Ave. cp. for all observers	.....	.....	.....	.....	.....	.....	.....	350	670	1890	8580
Min. cp. setting........	.....	.....	.....	.....	.....	.....	.....	130	225	430	1150
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Max. cp. setting.......	.....	.....	.....	.....	.....	858	1850	3250	16142	20800	34500
Ave. cp. for all observers	.....	.....	.....	.....	.....	360	840	1440	4790	6440	16100
Min. cp. setting........	.....	.....	.....	.....	.....	160	290	450	583	1150	3600
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Max. cp. setting.......	.....	.....	.....	.....	903	2568	8000	15850	15385	28500	44500
Ave. cp. for all observers	.....	.....	.....	.....	380	1170	3320	5550	5830	10600	27200
Min. cp. setting........	.....	.....	.....	.....	196	441	675	1200	1551	3250	13500
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Max. cp. setting.......	.....	735	1457	2499	5176	14770	18500	24400	23975	48000	73500
Ave. cp. for all observers	.....	280	570	1190	3040	6780	8950	11300	14800	25400	41900
Min. cp. setting........	.....	100	261	500	1335	2153	3600	4500	9000	16150	22550
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Max. cp. setting.......	1394	3044	7491	10704	15672	31324	60000	75250	88055	96000	98000
Ave. cp. for all observers	870	1920	3860	7240	11800	17400	27900	36200	42800	48500	51500
Min. cp. setting........	500	800	1500	5000	10000	9820	14250	17800	20355	22200	23000

POINTS ABOVE ROAD LEVEL

Angle above horizontal.	0°	0°	0°	0°	0°	1°	1°	1°	3°	3°
Angles left and right....	0°	2°	4°	8°	12°	0°	4°	8°	0°	4°
Station Number	A	62	E	64	65	C	D	69	71	73
Max. cp. setting.......	89651	25669	39192	3363	746	39200	21408	1602	3650	4900
Ave. cp. for all observers	46300	15900	9450	1150	320	21400	5650	630	2440	1520
Min. cp. setting........	22789	6500	906	320	150	12000	625	280	761	370

TABLE 5

Country Highways
Dry
Speed—25* and 40 miles per hour**
Observers—8
(7 at 25 mph., 6 at 40 mph.)

14-Foot Red Brick Pavement
No Street Lighting

Determinations—30
(19 at 25 mph., 11 at 40 mph.)

POINTS AT ROAD LEVEL

Distance ahead of car Angle below horizontal	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Ave. cp. for 25 mph						110	215	250	365	710	1660
Ave. cp. for 40 mph	....	...	.	...	.	.	—	350	670	1890	8580
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Ave. cp. for 25 mph	....	....	45	60	100	250	580	830	1180	1870	2310
Ave. cp. for 40 mph	....	.....	.....	...	..	360	840	1440	4790	6440	16100
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Ave. cp. for 25 mph	..	40	60	105	265	815	1600	2160	2640	2990	2840
Ave. cp. for 40 mph	....	...	..	...	380	1170	3320	5550	5830	10600	27200
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Ave. cp. for 25 mph	..	215	395	960	2120	4140	5160	5200	4430	3890	3090
Ave. cp. for 40 mph	.	280	570	1190	3040	6780	8950	11300	14800	25400	41900
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Ave. cp. for 25 mph	700	1700	2590	4950	8750	10500	8400	7200	5750	4320	3060
Ave. cp. for 40 mph	870	1920	2860	7240	11800	17400	27900	36200	42800	48500	51500

POINTS ABOVE ROAD LEVEL

Angle above horizontal Angles left and right	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Ave. cp. for 25 mph	2070	1730	1075	380	170	930	685	265	270	235	
Ave. cp. for 40 mph	46500	15900	9450	1150	320	21400	5650	650	2440	1520	

*From Table 1 **From Table 4

TABLE 6

Suburban Highways
Dry
Speed—25 miles per hour
Observers—7*

24-Foot Red Brick Pavement
Poor Street Lighting–Wide Spacing

Determinations—10

POINTS AT ROAD LEVEL

Distance ahead of car...	25′	29′	35′	44′	60′	88′	115′	140′	175′	250′	440′
Angle below horizontal.	7°	6°	5°	4°	3°	2°	1.5°	1.25°	1°	0.7°	0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Max. cp. setting.......	.....	.....	.....	.....	.....	600	900	1000	1050	1350	2550
Ave. cp. for all observers	.....	.....	.....	.....	.....	174	262	304	366	542	1397
Min. cp. setting........	.....	.....	.....	.....	.....	35	50	70	100	250	583
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Max. cp. setting.......	.....	.....	140	180	295	880	1200	1350	1950	2450	3900
Ave. cp. for all observers	.....	.....	76	101	170	346	528	637	901	1592	2527
Min. cp. setting........	.....	.....	10	25	30	80	130	200	440	970	1470
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Max. cp. setting.......	.....	150	180	317	572	1360	2250	2500	3000	4200	5600
Ave. cp. for all observers	.....	69	106	174	327	804	1222	1687	2271	3048	3444
Min. cp. setting........	.....	25	25	40	75	145	500	930	1300	1660	1897
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Max. cp. setting.......	.....	635	1110	1698	4700	6000	7100	8300	8300	7500	6800
Ave. cp. for all observers	.....	285	487	938	2913	3848	4996	5443	5519	4544	3882
Min. cp. setting........	.....	65	80	140	1730	2200	2700	2650	2600	2470	1810
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Max. cp. setting.......	2070	17000	7700	14400	24000	24500	18000	14000	11400	9200	7500
Ave. cp. for all observers	919	4149	3319	6467	11671	12387	10311	8583	7040	5290	4166
Min. cp. setting........	206	424	800	1882	3622	4388	4300	4100	3795	2800	1700

POINTS ABOVE ROAD LEVEL

Angle above horizontal.	0°	0°	0°	0°	0°	1°	1°	1°	3°	3°	
Angles left and right....	0°	2°	4°	8°	12°	0°	4°	8°	0°	4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Max. cp. setting.......	5600	3400	2300	880	220	1900	1700	710	400	600	
Ave. cp. for all observers	3002	1997	1018	326	121	1030	596	259	227	258	
Min. cp. setting........	937	840	360	125	75	459	265	115	126	107	

*Light from half moon for one observer.

TABLE 7

Suburban Highways
Wet center with snow on both sides
Dry center with snow on one side
Speed—25 miles per hour
Observers—1

24-Foot Red Brick Pavement

Poor Street Lighting

Determinations—4
(2 for each condition)

POINTS AT ROAD LEVEL

Distance ahead of car. Angle below horizontal.	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Ave. cp. for wet center. Ave. cp. for dry center..	....	....	....	....	... ...	90 85	130 100	150 110	210 165	450 300	1650 1175
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Ave. cp. for wet center. Ave. cp. for dry center..	....	....	85 65	100 85	125 120	200 140	375 250	600 400	950 610	2050 1550	3600 2750
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Ave. cp. for wet center.. Ave. cp. for dry center..	....	60 45	115 85	155 130	225 175	910 550	1600 1050	2175 1600	3070 2160	3850 2900	4500 3975
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Ave. cp. for wet center.. Ave. cp. for dry center..	....	110 75	215 170	425 420	2480 1590	3500 2310	4600 3000	5650 4175	6210 4785	5550 4850	4875 4450
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Ave. cp. for wet center Ave. cp. for dry center..	175 110	310 235	800 610	1070 1080	4150 2600	6675 5050	7710 5775	7950 5910	7760 5820	6700 5400	5530 4700

POINTS ABOVE ROAD LEVEL

Angle above horizontal. Angles left and right....	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Ave. cp. for wet center Ave. cp. for dry center.	4070 3550	2800 2145	960 730	210 150	95 85	875 725	360 285	155 185	165 130	140 90	

TABLE 8

Suburban Highway
Dry
Speed—25 miles per hour
Observers—6*

30-Foot Red Brick Pavement
Poor Street Lighting

Determinations—6

POINTS AT ROAD LEVEL

Distance ahead of car... Angle below horizontal.	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Max. cp. setting.......	.....	.....	.....	.....	.....	350	550	600	690	1300	3000
Ave. cp. for all observers	.....	.....	.....	.....	.....	130	200	230	340	710	1610
Min. cp. setting.......	.....	.....	.....	.....	.....	50	70	100	180	380	600
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Max. cp. setting.......	.....	.....	90	110	300	550	800	1500	1800	3700	4200
Ave. cp. for all observers	.....	.....	50	70	140	250	510	820	1110	1900	2630
Min. cp. setting.......	.....	.....	25	50	70	125	450	500	885	1150	1650
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Max. cp. setting.......	.....	70	120	385	440	1320	3200	4800	5500	5600	4500
Ave. cp. for all observers	.....	40	70	155	235	790	1580	2180	2580	3250	3430
Min. cp. setting.......	.....	20	35	75	160	700	1200	1600	1630	1900	2000
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Max. cp. setting.......	.....	475	850	1285	3500	7700	11000	9900	8000	6000	5300
Ave. cp. for all observers	.....	190	315	790	2070	4270	5600	5700	5480	4720	3780
Min. cp. setting.......	.....	70	135	500	1420	2640	3500	3800	4000	3700	2000
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Max. cp. setting.......	1400	3000	8000	13000	19000	18000	13700	12200	10000	7300	5700
Ave. cp. for all observers	630	1310	2990	6170	11550	11360	9900	8750	7270	5400	3900
Min. cp. setting.......	500	985	1250	2300	9000	5700	5300	4900	4560	3000	2000

POINTS ABOVE ROAD LEVEL

Angle above horizontal. Angles left and right....	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Max. cp. setting.......	4300	3100	1800	680	200	1600	1100	450	400	350	
Ave. cp. for all observers	2710	2070	720	335	85	1030	580	225	285	215	
Min. cp. setting.......	2300	725	415	175	70	900	230	115	125	110	

*Light from half moon for one observer.

TABLE 9

Suburban Highway
Wet Center with Snow on both Sides
Speed—25 miles per hour
Observers—1

30-Foot Red Brick Pavement
Poor Street Lighting

Determinations—2

POINTS AT ROAD LEVEL

Distance ahead of car. Angle below horizontal	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Ave. cp. for wet and snow	..	....	....	....	....	207	125	175	197	525	1175
*Ave. cp. for dry and no snow	..	..	..	.	.	130	200	230	340	710	1610
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Ave. cp. for wet and snow	....	....	78	95	155	201	325	525	780	1575	2250
*Ave. cp. for dry and no snow	....	....	50	70	140	250	510	820	1110	1900	2630
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Ave. cp. for wet and snow	....	58	100	165	218	768	1550	1725	2205	2575	5075
*Ave. cp. for dry and no snow	...	40	70	155	235	790	1580	2180	2580	3250	3430
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Ave. cp. for wet and snow	....	105	207	563	2315	2863	3500	4100	5140	6925	7175
*Ave. cp. for dry and no snow	..	190	315	790	2070	4270	5600	5700	5480	4720	3780
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Ave. cp. for wet and snow	156	276	715	1350	3360	6250	8750	10200	10425	9775	8450
*Ave. cp. for dry and no snow	650	1310	2990	6170	11550	11360	9900	8750	7270	5400	3900

POINTS ABOVE ROAD LEVEL

Angle above horizontal. Angles left and right	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Ave. cp. for wet and snow	5300	2053	659	124	152	765	313	135	150	133	
*Ave. cp. for dry and no snow	2710	2070	720	335	85	1030	580	225	285	215	

*From Table 7.

TABLE 10

Country Road
Dry—Wet—Snow
Speed—25 miles per hour
Observers—5
(2 dry, *2 wet, 1 snow)

16-Foot Crushed Stone Surface
No Street Lighting

Determinations—5

POINTS AT ROAD LEVEL

Distance ahead of car... Angle below horizontal.	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Ave. cp. for dry road...	.....	.....	.....	.....	.....	70	92	150	382	875	2350
Ave. cp. for wet road...	.....	.....	.....	.....	.....	63	95	120	120	280	750
Cp. for snow..........	.....	.....	.....	.....	.....	20	30	35	80	200	390
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Ave. cp. for dry road...	.....	.....	37	60	82	170	595	1050	1350	2750	3850
Ave. cp. for wet road...	.....	.....	38	83	135	180	330	425	700	1175	2120
Cp. for snow..........	.....	.....	10	15	20	37	130	200	290	400	900
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Ave. cp. for dry road...	.....	40	57	95	192	1085	2200	3200	4050	4750	4950
Ave. cp. for wet road...	.....	31	43	180	190	510	920	1450	1550	3050	3150
Cp. for snow..........	.....	10	15	20	35	135	320	450	610	1100	1100
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Ave. cp. for dry road...	.....	137	262	995	2950	6450	9300	9000	7850	6650	5550
Ave. cp. for wet road...	.....	175	280	425	725	2350	4140	5450	6380	5650	3850
Cp. for snow..........	.....	23	65	130	430	1360	2200	2050	1810	1600	1200
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Ave. cp. for dry road...	900	1850	4350	8600	15000	16400	14650	13100	10700	7950	5600
Ave. cp. for wet road...	245	505	820	1550	4260	7290	8300	8500	8270	7170	4750
Cp. for snow..........	190	300	770	1650	5100	12700	7000	4000	2660	1800	1250

POINTS ABOVE ROAD LEVEL

Angle above horizontal. Angles right and left....	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Ave. cp. for dry road...	3950	3050	1550	360	132	1550	750	240	500	250	
Ave. cp. for wet road...	1640	975	418	158	81	530	215	104	154	116	
Cp. for snow..........	780	590	290	92	28	435	225	71	111	116	

*Light from half moon for one observer and wet road.

TABLE 11

Outlying Parkway
Dry
Speed—25 miles per hour
Observers—8*

24-Foot Dark Tarvia Pavement
No Street Lighting

Determinations—9

POINTS AT ROAD LEVEL

Distance ahead of car Angle below horizontal	25' 7°	29' 6°	35' 5°	44' 4°	60' 3°	86' 2°	115' 1.5°	140' 1.25°	175' 1°	250' 0.7°	440' 0.4°
Station (32.2' to side)						30	25	20	15	10	5
Max. cp. setting Ave. cp. for all observers Min. cp. setting.	. . .	. . ...	. ...	. ...	 . 	450 175 60	800 [illegible] 100	900 [illegible] 150	1000 620 110	4750 1470 [illegible]	4000 2210 800
Station (18.8' to side)			44	39	34	29	24	19	14	9	4
Max. cp. setting Ave. cp. for all observers Min. cp. setting.	.. . .	. . ...	150 80 30	200 100 50	800 250 120	880 450 240	1900 1020 500	3100 1800 550	6500 2100 445	5700 2710 1100	4500 2920 1130
Station (12.8' to side)		48	43	38	33	28	23	18	13	8	3
Max. cp. setting Ave. cp. for all observers Min. cp. setting.	. ... .	120 70 30	200 110 40	520 220 60	1700 610 330	4150 1530 800	7400 2620 700	9400 3680 1350	10000 4090 1170	6000 3700 1400	5300 3500 1620
Station (6.2' to side)		47	42	37	Q	F	P	17	12	7	2
Max. cp. setting . . . . Ave. cp. for all observers Min. cp. setting.	.	650 350 120	1300 775 300	2200 1430 900	4900 2650 650	11000 4500 2000	12500 5230 3100	11300 6720 2130	9500 5880 2200	7100 4900 2200	5580 3580 1850
Station (0' to side)	51	46	41	36	31	26	21	M	B	6	1
Max. cp. setting Ave. cp. for all observers Min. cp. setting.	1610 810 500	1970 1200 600	3000 2480 1800	10500 4970 1000	14700 9670 3000	18650 10100 3000	16250 6700 2600	13650 7810 1170	11000 6750 3250	8450 5210 2500	5900 3320 1800

POINTS ABOVE ROAD LEVEL

Angle above horizontal Angles left and right	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Max. cp. setting Ave. cp. for all observers Min. cp. setting.	4350 2300 800	3500 2550 800	3000 1480 215	1100 290 150	265 180 90	1600 980 330	1150 645 210	500 270 120	800 300 130	400 200 115	

*Light from half moon for one observer.

TABLE 12

Outlying Parkway
Wet—Snow
Speed—25 miles per hour
Observers—2
(1 wet, 1 snow)

24-Foot Dark Tarvia Pavement
No Street Lighting

Determinations—2

POINTS AT ROAD LEVEL

Distance ahead of car... Angle below horizontal.	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Cp. for wet surface.....	.....	.....	.....	.....	.....	320	400	450	520	700	1900
Cp. for snow-covered...	.....	.....	.....	.....	.....	50	50	60	135	330	520
*Ave. cp. for dry.......	.....	.....	.....	.....	.....	175	280	365	620	1470	2210
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Cp. for wet surface.....	.....	.....	150	250	420	500	750	800	1300	2600	4200
Cp. for snow-covered...	.....	.....	25	35	50	70	250	300	570	650	1100
*Ave. cp. for dry.......	.....	.....	80	100	250	450	1030	1880	2100	2710	2920
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Cp. for wet surface.....	.....	100	200	400	600	1400	1150	3500	4000	5100	6100
Cp. for snow-covered...	.....	20	30	40	70	290	700	820	970	1470	1150
*Ave. cp. for dry.......	.....	70	110	220	610	1530	2620	3680	4090	3700	3500
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Cp. for wet surface.....	.....	185	580	2300	6200	7700	9000	9800	10000	8100	6900
Cp. for snow-covered...	.....	45	120	295	1150	2500	2900	2700	2260	1750	1130
*Ave. cp. for dry.......	.....	350	775	1430	2850	4560	5230	6720	5880	4900	3580
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Cp. for wet surface.....	600	1400	2800	6500	12500	16000	15500	14000	12000	10000	7700
Cp. for snow-covered...	330	570	1410	3250	7600	13900	8500	6000	3020	1900	1300
*Ave. cp. for dry.......	810	1200	2480	4870	9670	10360	8790	7810	6750	5210	3520

POINTS ABOVE ROAD LEVEL

Angle above horizontal. Angles left and right....	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Cp. for wet surface.....	4500	3000	1300	450	300	1100	600	300	250	200	
Cp. for snow-covered...	910	720	480	175	55	530	390	125	165	185	
*Ave. cp. for dry.......	2300	2550	1480	290	180	980	645	270	360	260	

*From Table 10.

TABLE 13

Outlying Parkway
Dry
Speed—40 miles per hour
Observers—1

24-Foot Dark Tarvia Pavement
No Street Lighting

Determinations—2

POINTS AT ROAD LEVEL

Distance ahead of car Angle below horizontal	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Cp. for observer	...	...	...	...	...	...	...	300	880	3100	13000
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Cp. for observer	...		...	...	...	380	1100	2000	8650	10200	15000
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Cp. for observer	...	...	...	...	400	1610	5200	9300	9050	15400	12100
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Cp. for observer		320	810	2150	3400	9850	11000	14000	13100	9800	11400
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Cp for observer	720	1650	2300	4030	8630	6910	9000	9650	10400	11000	11300

POINTS ABOVE ROAD LEVEL

Angle above horizontal Angles left and right	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Cp. for observer	11700	13200	13800	1960	330	8100	11000	930	1650	2000	

TABLE 14

City Thoroughfare
Dry
Speed—25 miles per hour
Observers—4*

50-Foot Dark Asphalt
Fair Street Lighting

Determinations—4

POINTS AT ROAD LEVEL

Distance ahead of car... Angle below horizontal.	25′ 7°	29′ 6°	35′ 5°	44′ 4°	60′ 3°	88′ 2°	115′ 1.5°	140′ 1.25°	175′ 1°	250′ 0.7°	440′ 0.4°
Station (32.2′ to side)						30	25	20	15	10	5
Max. cp. setting........	.....	.....	.....	.....	.....	340	600	600	620	980	3200
Ave. cp. for all observers	.....	.....	.....	.....	.....	145	230	250	325	580	1450
Min. cp. setting........	.....	.....	.....	.....	.....	25	50	50	90	250	400
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Max. cp. setting........	.....	.....	400	500	1000	1400	1250	1200	1700	3600	4400
Ave. cp. for all observers	.....	.....	150	190	335	465	625	760	1000	1710	2210
Min. cp. setting........	.....	.....	10	15	25	46	200	230	375	450	700
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Max. cp. setting........	.....	250	500	1300	1600	2240	2750	4700	5600	5700	4850
Ave. cp. for all observers	.....	92	185	430	560	1020	1540	2260	2550	3010	2530
Min. cp. setting........	.....	10	15	25	46	187	450	600	620	850	800
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Max. cp. setting........	.....	2280	3990	5920	5300	8400	11800	11100	9000	7600	4500
Ave. cp. for all observers	.....	625	1190	1910	2510	4210	5410	5620	5210	3940	2260
Min. cp. setting........	.....	30	78	195	745	1580	1650	1700	1430	1150	850
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Max. cp. setting........	2260	4410	7360	8750	9700	13000	10500	13000	10000	7200	4400
Ave. cp. for all observers	770	1510	2770	4240	6670	8520	7050	6960	5580	4120	2500
Min. cp. setting........	95	360	910	2110	2810	3060	2900	2920	1820	1100	800

POINTS ABOVE ROAD LEVEL

Angle above horizontal. Angles left and right....	0° 0°	0° 2°	0° 4°	0° 8°	0° 12°	1° 0°	1° 4°	1° 8°	3° 0°	3° 4°	
Station Number	A	62	E	64	65	C	D	69	71	73	
Max. cp. setting........	2700	3400	2000	483	370	1150	800	324	400	280	
Ave. cp. for all observers	1489	1543	911	277	167	640	420	186	229	185	
Min. cp. setting........	570	450	310	112	37	460	233	81	100	90	

*Light from half moon for one observer.

TABLE 15

1. **Country Highways**—From Table 1, 14-Foot Red Brick Pavement, No Street Lighting.
2. **Suburban Highways**—From Table 6, 24-Foot Red Brick Pavement, Poor Street Lighting.
3. **Suburban Highway**—From Table 8, 30-Foot Red Brick Pavement, Poor Street Lighting.
4. **Country Road**—From Table 10, 16-Foot Crushed Stone Surface, No Street Lighting.
5. **Outlying Parkway**—From Table 11, 24-Foot Dark Tarvia Pavement, No Street Lighting.
6. **City Thoroughfare**—From Table 14, 50-Foot Dark Asphalt Pavement, Fair Street Lighting.

Dry

Speed—25 miles per hour

POINTS AT ROAD LEVEL.

Distance ahead of car	25'	29'	35'	44'	60'	88'	115'	140'	175'	250'	440'
Angle below horizontal	7°	6°	5°	4°	3°	2°	1.5°	1.25°	1°	[illegible]	0.4°
Station 32.2' to side						30	25	20	15	10	5
Ave. cp. for road No. 1						110	215	[illegible]	365	710	1660
Ave. cp. for road No. 2						174	262	304	366	542	[illegible]
Ave. cp. for road No. 3						130	200	230	340	710	1610
Ave. cp. for road No. 4						70	92	150	382	875	2350
Ave. cp. for road No. 5						175	280	365	620	1470	2210
Ave. cp. for road No. 6						145	230	250	325	[illegible]	1450
Station 18.5' to side			44	39	34	29	24	19	14	9	4
Ave. cp. for road No. 1			45	60	100	250	580	830	1130	1870	2310
Ave. cp. for road No. 2			76	101	170	346	528	637	9[illegible]1	1592	2527
Ave. cp. for road No. 3			50	70	140	250	510	820	1110	1900	2630
Ave. cp. for road No. 4			37	60	82	170	595	1050	1350	2750	3850
Ave. cp. for road No. 5			80	100	250	450	1030	1880	2100	2710	2920
Ave. cp. for road No. 6			150	190	335	465	625	760	1000	1710	2210
Station 12.8' to side		48	43	38	33	28	23	18	13	8	5
Ave. cp. for road No. 1		40	60	105	265	815	1690	2160	2640	[illegible]	2840
Ave. cp. for road No. 2		69	106	174	327	804	1222	1697	2271	3045	3444
Ave. cp. for road No. 3		40	70	155	235	790	1580	2180	2560	2250	3430
Ave. cp. for road No. 4		40	57	95	192	1025	2200	3240	[illegible]	4730	4950
Ave. cp. for road No. 5		70	110	220	610	1530	2620	2600	[illegible]	3100	2500
Ave. cp. for road No. 6		92	185	420	560	1020	1540	2260	[illegible]	3010	2530
Station 6.2' to side		47	42	37	Q	F	P	17	12	7	2
Ave. cp. for road No. 1		215	395	960	[illegible]	4140	5160	[illegible]	[illegible]	[illegible]	3090
Ave. cp. for road No. 2		285	487	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4544	[illegible]
Ave. cp. for road No. 3		190	315	790	2070	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 4		137	262	995	[illegible]	6450	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 5		350	[illegible]	1430	2850	4560	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 6		625	1190	1910	[illegible]	4210	5410	[illegible]	[illegible]	[illegible]	2260
Station 0' to side	51	46	41	36	31	26	21	M	B	6	1
Ave. cp. for road No. 1	700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 2	919	1712	3319	6467	11671	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4166
Ave. cp. for road No. 3	630	1310	2990	6170	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 4	[illegible]	1650	[illegible]	8600	15000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5600
Ave. cp. for road No. 5	810	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 6	770	1310	2770	4240	6670	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

POINTS ABOVE ROAD LEVEL.

Angle above horizontal	0°	0°	0°	0°	0°	1°	1°	1°	3°	3°
Angles left and right	6°	2°	4°	8°	12°	0°	4°	8°	0°	4°
Station Number	A	62	E	64	65	C	D	69	71	73
Ave. cp. for road No. 1	[illegible]	[illegible]	[illegible]	[illegible]	120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 2	[illegible]	[illegible]	1018	326	121	1030	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 3	2710	2070	720	335	85	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 4	[illegible]	[illegible]	1550	360	132	1150	[illegible]	240	[illegible]	[illegible]
Ave. cp. for road No. 5	[illegible]	[illegible]	[illegible]	290	150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ave. cp. for road No. 6	[illegible]	1543	911	277	162	640	420	[illegible]	229	185

TABLE 16

Country Highways
Dry
Speed*—25 and 40 miles per hour
Observers—8
(7 at 25 mph., 6 at 40 mph.)

14-Foot Red Brick Pavement
No Street Lighting

Determinations—30
(19 at 25 mph., 11 at 40 mph.)

POINTS AT ROAD LEVEL

Distance ahead of car...	25′	29′	35′	44′	60′	88′	115′	140′	175′	250′	440
Angle below horizontal.	7°	6°	5°	4°	3°	2°	1.5°	1.25°	1°	0.7°	0.4°
Station (32.2′ to side)						30	25	20	15	10	5
*Ave. f. c. for 25 mph..	.....	.....	.....	.....	.....	.014	.016	.013	.011	.011	.009
Ave. f. c. for 40 mph...	.....	.....	.....	.....	.....	.....	.....	.018	.022	.030	.044
Station (18.8′ to side)			44	39	34	29	24	19	14	9	4
Ave. f. c. for 25 mph...	.....	.....	.037	.031	.028	.032	.044	.042	.039	.030	.012
Ave. f. c. for 40 mph...	.....	.....	.....	.....	.....	.047	.064	.073	.156	.103	.083
Station (12.8′ to side)		48	43	38	33	28	23	18	13	8	3
Ave. f. c. for 25 mph...	.....	.048	.049	.054	.074	.105	.121	.110	.086	.048	.015
Ave. f. c. for 40 mph...	.....	.....	.....	.....	.106	.151	.251	.283	.190	.170	.140
Station (6.2′ to side)		47	42	37	Q	F	P	17	12	7	2
Ave. f. c. for 25 mph...	.....	.255	.323	.496	.590	.534	.390	.265	.145	.062	.016
Ave. f. c. for 40 mph...	.....	.332	.465	.613	.847	.875	.677	.577	.483	.407	.216
Station (0′ to side)	51	46	41	36	31	26	21	M	B	6	1
Ave. f. c. for 25 mph...	1.12	2.02	2.11	2.56	2.43	1.36	.635	.367	.178	.069	.016
Ave. f. c. for 40 mph...	1.39	2.28	3.15	3.74	3.28	2.25	2.11	1.85	1.40	.777	.266

*The foot-candle values apply for the illumination on a surface normal to the beam and are calculated from the candlepower data of Table 5.

DISCUSSION

The Report of the Committee on Motor Vehicle Lighting and the papers by Messrs. Magdsick and Falge and Mr. Devine were discussed together. See page 518.

MOTOR VEHICLE HEADLIGHTING IN MASSACHUSETTS*

BY A. W. DEVINE**

A specific law regulating the use of motor vehicle headlights was first made in Massachusetts when the Highway Commission adopted its much-copied regulations on October 27, 1915. These regulations provided that wherever there was not sufficient light on the highway to make all substantial objects visible for a distance of at least 150 ft., the lamps which a motor vehicle was required to display, should throw sufficient light ahead to make clearly visible any such object within the specified distance. They provided further that any light thrown ahead or sidewise should be so directed that no dazzling rays should at any time be more than 3.5 ft. above the ground 50 ft. or more ahead of the vehicle, and that such light should be sufficient to show any substantial object 10 ft. on each side 10 ft. ahead of the vehicle.

These regulations remained in force until August 15, 1921. Hundreds of motorists were prosecuted by highway commission inspectors and police officers and substantial fines were imposed in most cases for violation of them. The method used in enforcement was for a properly qualified officer to select a point on a straight, level, unlighted roadway from which approaching vehicles would be visible for a distance of about an eighth of a mile in either direction. From this point he would measure off 50 ft. in either direction and would observe the light from approaching vehicles from the time they came into view until they were within 50 feet of him, in the meantime walking back and forth across the road so as to observe the approaching light more carefully. To avoid the possibility of any mistake, only those vehicles were stopped which had the most glaring lamps. If it was apparent to the officer that some attempt had been made to regulate the light properly by applying a device or frosting the

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**Department of Public Works, State of Massachusetts

glass, the motorist was allowed to proceed with a caution to properly adjust the lamps on his machine. The operators of vehicles on which no attempt had been made to regulate the light were summoned into court on a charge of violating the regulations and in all except a few instances were fined.

Often such enforcement was preceded by educational work. On certain nights in different parts of the state motorists would be invited to congregate at certain points and have their lighting equipment examined by some competent inspector, who pointed out defects and faulty adjustment and advised them as to the proper method of correcting such defects.

It became apparent as time went on that the regulations were not very effective. As a result of the enforcement work, motor vehicles were equipped with all kinds of so-called glare eliminating devices, only a few of which had any real value. The lower courts accepted the statement of prosecuting officers that the lamps on the vehicles operated by the defendents were glaring only if no evidence was introduced to show that the operator had made an attempt to reduce the glare. If, however, the operator had made a reasonable effort to control the glaring rays from his headlamps, with no matter what results, it was exceedingly difficult to secure a conviction of violating the regulations. Accessory dealers who sold lenses and other devices were working against the interests of safe driving by selling inefficient devices and erroneously advising motorists. This was done largely through ignorance, but, by leading the motorist to believe that all that was necessary to comply with the law was to install the device in question, it nullified whatever good results might have ensued from the attempted enforcement of the regulations.

The Massachusetts Highway Commission was never willing to approve of headlighting devices which would comply with the intent of the law because they maintained that it was not a question of the device used, but almost wholly a question of the adjustment. Furthermore, there was not sufficient data available at that time for the formulation of a more effective law. While it was a well known fact that headlighting conditions were not improving any but were probably growing worse on account of

the larger number of motor vehicles on the highways, very little was done to improve the conditions. This was probably due mostly to the fact that there was a general feeling that the problem could not be solved and no hope of much improvement offered.

Such was the condition when the state departments were reorganized on December 1, 1919. The Highway Commission was absorbed by the larger Department of Public Works under the leadership of John N. Cole, the commissioner. Under the provisions of the reorganization law, he appointed a registrar of motor vehicles who was to take over all the powers of the Highway Commission relative to motor vehicles and named Frank A. Goodwin to hold this important office.

Mr. Goodwin, who is an energetic man of great initiative, realized the importance of having an active bureau of statistics and immediately formed such a bureau in order that he might have available at short notice such information as would be helpful in reducing the number of accidents and saving lives. It became evident to him almost immediately that something would have to be done to correct the lighting situation. Operators of motor vehicles who were involved in night accidents complained largely that they were blinded by the light from an approaching vehicle. Many persons walking by the side of the road or stepping out into the road from the side were seriously injured or killed at night because the operators of motor vehicles failed to see them.

At about this time, the summer of 1920, we were fortunate in having an illustrated lecture on the Illuminating Engineering Society's headlighting specifications by Mr. W. F. Little at the Massachusetts Automobile Club in Boston. Shortly after that, Mr. Goodwin detailed me to make a thorough, practical study of the headlighting problem and formulate regulations for the control of motor vehicle headlighting. In view of what we learned of the enforcement of the motor vehicle laws in Connecticut, where the Society's specifications have been adopted, it was decided that we would attempt to work out specifications along somewhat similar lines.

Through the kindness of C. N. Chamberlin and C. A. B. Halvorson, Jr., of the General Electric Company at Lynn, Mass. a

dark room over 60 ft. long and certain necessary instruments were placed at my disposal. Here I determined the light distribution characteristics of some 30 devices. A pair of accurate paraboloidal reflectors, of 1⅜ in. focal length was mounted similarly to the lamps of a car 60 ft. from a screen. Using lamps of 21 measured mean spherical candlepower, intensities of the combined beam of the two lamps were measured all over the illuminated field. This was done to obtain results comparable with those existing in actual practise. The lenses tested were of 9 in. and 9¼ in. sizes.

Having completed this work a car was equipped with the lamps used in the laboratory tests. These lamps were mounted on universal brackets so that aiming adjustments could be easily made, and another pair of lamps was mounted beside them for purposes of comparison. Outdoor night tests under all kinds of driving conditions were made over a period of several months, using those devices which were tested in the laboratory and others which were not available at the time of making the laboratory tests. These devices represented all types except diffusion devices, which had already been ruled out of use in several states which used the Society's specifications. They included types of devices which varied from those which simply deflected the light downward without spreading it to those which spread the light through an angle of about 90.°

As a result of these tests and the experience of our investigating department, it was determined that a minimum spread of beam sufficient to cover a 12 ft. roadway would be required for the safety of the users of the highways. It was also determined that the Society's specifications glare limits were reasonable, and no attempt was made to modify them. These limits are: 2,400 cp. maximum at a point 100 ft. ahead of the car, 5 ft. above the ground, and 800 cp. maximum at a point 7 ft. to the left of that point.

The next step was to determine what intensities should be required in different parts of the beam. The Society's specifications for road performance required a normal illumination of 0.12 foot-candles at the A or B and E or F points. This value was found to be a low minimum in actual road test, particularly so in the case of a number of devices with which, because of the

fact that they projected a beam of rapidly varying intensities from one point to a nearby point, it was found almost impossible to see an object illuminated to a corresponding brightness. In view of the fact that the Headlighting Committee had established such a low and unusually fair minimum, we felt that it would not be acceptable in making laboratory tests. My road tests and laboratory tests compared showed that under fair conditions of actual use the depreciation in lighting equipment would cause a reduction in illumination of about fifty per cent. This was due to a decrease in the reflection coefficients of the reflectors, a of the lamp bulbs. For this reason we decided that as far as the laboratory tests were concerned we would double the requirements of the Society's specifications for road performance and call for an illumination of 0.25 foot-candles at such points as we decided to make tests. This is in line with the Headlighting Committee's proposals to the Standards Committee of the S. A. E. as published in the I. E. S. TRANSACTIONS for 1920 on page 850.

Having decided on the basis upon which our specifications for laboratory test were to be drawn, it was a relatively simple matter to select the test points and establish the required intensities at those points. In practise headlamps are ordinarily mounted at a height varying from 34 to 38 in. above the ground, but for purposes of laboratory test, the lamps were assumed to be at a height of 42 in. above the ground. This assumption results in greater freedom from glare in practise, but if not corrected for in computing the required minimum intensities in the beam, would mean that those devices which complied with the specifications would not necessarily have sufficient spread to cover a 12 ft. roadway as desired. For this reason, those minimum laboratory test points were selected which, with the centers of the lamps at an assumed height of 42 in., would indicate the parts of the beam decrease in the impressed voltage on the lamps and deterioration which strike the edges of a 15 ft. flat roadway, or, under average actual conditions, would indicate the parts of the beam which strike the edges of a 12 ft. roadway. Our P and Q points are those points in the beam which strike the edges of a 12 ft. roadway 115 ft. and 57 ft. respectively ahead of the car when the lamps are 36 in. above the ground. The M point is the test point at which is measured the intensity directly ahead of the car 1.25

degrees below the horizontal. This point is 0.25 degree lower than the Society's B point. While we would have preferred, if possible, to retain the B point, the corresponding candlepower requirement (10,000) would have caused several satisfactory devices to fail to comply with the specifications. Furthermore, it might result in the design of devices with too sharp a cut-off or which approached the glare limits at C and D too closely, resulting in excessive glare when the molds in which the lenses are made had worn slightly. Neither did we feel that illumination up to a distance of 200 ft. ahead was necessary for safe driving at a reasonable speed. Our new regulations were drawn to call for illumination up to a distance of 160 ft., an increase of 10 ft. over the old regulations. The wording of the specifications for laboratory test was taken from the Society's specifications with a few changes. A copy of part of these specifications is contained in Appendix A.

Considerable thought was given to the method of enforcement to be employed before formulating regulations. One method was to adopt that used in Connecticut, where, under the able direction of Alden L. McMurtry, more has been accomplished along this line, I believe, than in any other state. To do so would have meant that, having decided on a more rigid set of specifications for laboratory test, we would have to adopt a different set of specifications for road performance. Mr. McMurtry kindly placed all of the information which he had gained at our disposal and his experience and advice were of very great help to us. H. H. Magdsick also rendered invaluable aid by supplying us with accurate information from his practical knowledge of the subject. We believed that the use of a portable photometer in testing the road performance of lighting equipment was not entirely practical, and it was finally decided that the use of double specifications was undesirable. To secure compliance with the law, it would be necessary to educate the public to make proper adjustments under any system, and adding the use of a photometer only complicated the problem.

The alternative method then suggested itself, that enforcement could be had on the basis of condition and adjustment of equipment. A bill had been introduced in the legislature, and on May 26th, 1921, it became law, requiring that "No headlamp shall

be used upon any motor vehicle (operated during the period from one-half hour after sunset to one-half hour before sunrise) unless such lamp is equipped with a lens or other device, approved by the registrar, designed to prevent glaring rays." Regulations were drawn up requiring that headlamps be used on insufficiently lighted ways, that every approved device be applied and adjusted as required by the registrar's approval, that light sources of 21 cp. only be used and that any reflectors used as a part of such headlamps should have highly polished silvered or glass reflecting surfaces. These regulations which went into effect on August 15, 1921, are given in full in Appendix B.

One of the new requirements is that the light source used in any headlamp must be of 21 cp.,—no more and no less. Other states have limited the maximum candlepower which could be used and we felt that it was necessary to set a minimum candlepower as well, in order that the motorist might not be troubled so much by insufficient illumination and also in order that poor visibility due to the contrast in the illuminated fields ahead of two approaching vehicles might be reduced. By making these limits the same and standardizing on one size of light source, this contrast is reduced to a minimum, not to mention the beneficial results which accrue from the elimination of the many sizes of electric bulbs which dealers have heretofore stocked. It might be argued that it is practically impossible, even under the most favorable conditions, to maintain an electric bulb at 21 cp. The answer to this is that in interpreting laws their intent, which cannot always be exactly stated, must be taken into consideration. In this case I should consider that if a bulb of 21 rated candlepower were used, a reasonable variation in candlepower above or below this figure would not be a violation of the regulations. In addition to the requirement of the regulations that only 21 cp. light sources be used, all approvals of electric headlamp devices which have so far been issued require the use of a type C (gas filled) bulb. This requirement is made not only to further standardize on equipment, but also on account of the higher efficiency and slower depreciation of the type C bulb. The new law in Massachusetts calls, then, for the use of an approved device, 21 cp. type C bulb (in electrical equipment), highly polished reflectors and proper adjustment of the device. In enforcement, the first three con-

ditions of equipment are easily checked up and the fourth is a simple matter if a proper testing stand is arranged at points where violators of the law are to be stopped. The specifications for test were submitted, after being completed, to Prof. Wm. J. Drisko of the Massachusetts Institute of Technology and, except for several minor recommendations, were approved by him and recommended for use. Forty-three applications for approval of electric headlighting devices were received and tested up to Aug. 15, 1921. Of these twenty-six devices were approved for use; of the devices which were not approved fourteen failed to comply with the limiting test intensities and three devices were refused approval although they complied with the limiting intensities. Two of the devices which were refused approval were deemed to be unsafe for use on account of unduly dark and bright areas within the area outlined by the specified points and one was refused approval because of unduly difficult and complicated adjustment.

The results of the tests of devices for approval clearly shows that the requirements are much more severe in Massachusetts than in states which have adopted the Society's specifications. Our experience has already proven, however, that it is practically impossible to specify reasonable limiting test intensities which can not be complied with by inferior devices. I believe that those states which adopt test specifications for approval of devices should not lose sight of the value of a section in such specifications reserving to them the right to refuse approval of any device which, although it conforms to the specified limiting intensities, is liable to prove unsafe because it does not comply with the intent of the specifications or unsatisfactory because it has an unduly complicated adjustment. Such a section is included in the Society's specifications and was copied in the Massachusetts specifications. Its importance is shown by the fact that, in spite of our more severe specifications, the registrar exercised the right reserved therein in the case of three of the devices which complied with the limiting intensities.

The attempt to solve the headlighting problem in Massachusetts was not made without full realization of the difficulties which must be overcome. To secure good results the interest of the motorist must be with us. We cannot obtain his interest by

approving for his use devices which will cause him any dissatisfaction when properly adjusted. This was one reason for our more severe specifications.

Education of the motorist to the necessity of making proper adjustment of his headlamps and keeping his lighting equipment in good order is of prime importance. A novel method of educating the public is being used. A circular disc of heavy paper, perforated with two 0.25-in. holes, spaced 4 in. apart and equally distant from the center on the same diameter, is being issued. On this disc is printed the requirements of the law, the approved list, and focusing and aiming instructions. The disc is used for focusing the lamps by holding it in front of the lamp being focused without the device in place. Two filament images are projected on a vertical surface 25 ft. from the lamp, one image from the top part and one from the bottom of the reflector. The relative position of these images, one to the other, determines the focal adjustment. This focusing disc has met with great popularity, so much so that some difficulty has been experienced in supplying the demand.

Another important consideration is that for persons who have not the inclination or ability to adjust their own lamps, some place should be available where they can go to have the lamps adjusted. For this purpose complete printed instructions are being issued and competent persons who have the proper facilities are being approved of. Eleven trained inspectors from the Registry of Motor Vehicles are travelling throughout the state instructing and examining mechanics and others who seek official certification of their competency.

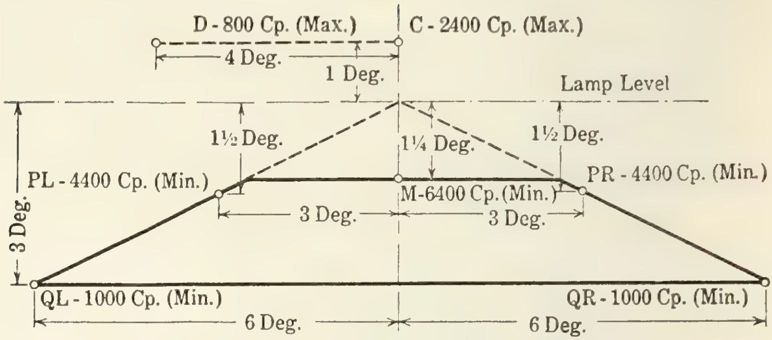
It is the intention of our department to finish the work which has been started, without sparing either expense or effort, and we believe that the results will mean a big improvement in automobile headlighting.

APPENDIX A

(From Mass. Specifications—Test No. 1.)

Tests.

The lamps shall be adjusted to give their rated candlepower at rated efficiency. Measurements shall be made at the following points at the surface of the screen:



Massachussetts Specifications Test Point Locations.

C. In the median vertical plane parallel to the lamp axes, one degree of arc above the level of the lamps.

D. Four degrees of arc to the left of this plane and one degree of arc above the level of the lamps.

M. In the median vertical plane parallel to the lamp axes, one and one-quarter degrees of arc below the level of the lamps.

PL. Three degrees of arc to the left of this plane and one and one-half degrees of arc below the level of the lamps.

PR. Three degrees of arc to the right of this plane and one and one-half degrees of arc below the level of the lamps.

QL. Six degrees of arc to the left of this plane and three degrees of arc below the level of the lamps.

QR. Six degrees of arc to the right of this plane and three degrees of arc below the level of the lamps.

In an acceptable device both pairs of samples shall conform to the following specifications for the observed apparent candlepower:

Point C. The apparent candlepower shall not exceed 2,400.

Point D. The apparent candlepower shall not exceed 800.

Point M. The apparent candlepower shall not be less than 6,400.

Points PL and PR. At each of these points and at every point on a line between them the apparent candlepower shall not less than 4,400.

Points QL and QR. At each of these points and at every point on a line between them the apparent candlepower shall not be less than 1,000.

APPENDIX B

COMMONWEALTH OF MASSACHUSETTS DEPARTMENT OF PUBLIC WORKS

Registry of Motor Vehicles.

RULES AND REGULATIONS CONCERNING HEADLAMPS ON MOTOR VEHICLES.

Acting in pursuance of the authority conferred by section thirty-one of chapter ninety of the General Laws the rules and regulations relative to lights on motor vehicles made by the Massachusetts Highway Commission, under corresponding provisions of earlier laws, are hereby rescinded, and the following are declared adopted in lieu thereof; the same to be effective August 15, 1921:

Section 1.—If and when, during the period when motor vehicles are required to display lights by section seven of chapter ninety of the General Laws, and amendments thereof, there is not sufficient light within the traveled portion of the highway to make clearly visible all vehicles, persons or substantial objects within a distance of at least one hundred and sixty feet, no automobile shall be operated unless it is equipped with two lighted headlamps of approximately equal candlepower which shall throw sufficient light ahead to make clearly visible all vehicles, persons or substantial objects upon the roadway within a distance of one hundred and sixty feet; and no motorcycle shall be operated unless it is equipped with one headlamp which shall throw sufficient light ahead to make clearly visible all vehicles, persons or substantial objects upon the roadway within a distance of one hundred and fifteen feet.

Section 2.—Every lens or other device designed to prevent glaring rays, the use of which on motor vehicles has been approved by the registrar, as provided in said section seven, shall be applied and adjusted in accordance with the requirements of the certificate approving the use thereof. Every lamp bulb or

light used in any headlamp on a motor vehicle shall be of twenty-one mean spherical candlepower. Every reflector which is used as a part of such headlamp shall have a highly polished silvered or glass reflecting surface and shall be free from dents, rust and other imperfections.

SECTION 3.—The operator of every motor vehicle shall permit any police officer or motor vehicle investigator and examiner to inspect the headlighting equipment of such motor vehicle and to make such tests as may be necessary to determine whether the provisions of section two are being complied with.

DISCUSSION

The Report of the Committee on Motor Vehicle Lighting and the papers by Messrs. Magdsick and Falge and Mr. Devine were discussed together.

J. A. HOEVELER: The subject of enforcement of motor vehicle headlight laws is one, I think, of prime importance. We now have satisfactory laws in quite a few states, and a large percentage of the cars are now operating under them, but I am not so sure if in any of the states the enforcement is adequate to secure compliance with the law. We therefore should next turn our attention to making these laws effective by helping the enforcement.

Now, at first I had the idea that police officers might be induced to use foot-candle meters and a number of police departments in Wisconsin bought them, but police officers are afraid of the proposition; they have the idea that the motorist will be suspicious of what is being done.

Therefore, I think testing stations must be provided; testing stations in which a car can be driven and the motorist himself can see that he is violating the law or complying with it, as the case may be. In Milwaukee, a testing station has been operating on this principle for about a month and a half.

The test station is arranged in this way: There are three sets of guide rails in one end of the station into which three cars may be backed; one hundred feet ahead is placed a test board, which is movable on a track, and can be placed in front

of each of the three cars successively. On this test board are located four bull's-eyes, corresponding to the various test positions specified in the Wisconsin law. They are translucent, and they are supplied with illumination from chambers at the rear of the board. The illumination is of such brightness as to equal the brightness that the law specifies at that particular point. The two upper bull's eyes represent the glare points, and the two lower ones the road-lighting points. The upper ones are marked, "Light, Light," with large letters, and the two lower ones are marked, "Dark, Dark." The motorist turns on his lights, speeds his engine to get maximum candlepower, and with one glance both he and the officer in charge can tell whether or not the headlamps are in compliance with the law.

If the two lower bull's-eyes are dark, relative to their background, that is an indication that the motorist is supplying more than the minimum required road-light. If the two upper bull's-eyes remain light, it is an indication that he is not violating the glare rules.

This station is operated by two police officers; one is stationed at the guide rails where he can properly spot the cars, and the other at the board, to shift same as needed. The one who spots the cars also takes care of the records. The man who shifts the board watches the voltmeter and keeps lamp voltage at the board at proper value by means of a rheostat. The test station was installed by the Bureau of Illumination Service of which Howard F. Ilgner is illuminating engineer. Milwaukee was able to put this station into operation because it had an illuminating department, but most cities are not so fortunately situated.

While the police department operates the test station, the Bureau of Illumination Service supervises it and keeps it operating properly and keeps the board properly checked up. The station is now operated in an old garage and will be closed for the winter, but a good showing has been made, and it is believed that a permanent station can be secured.

The motor vehicle officers send the motorists in. They give them a card when they stop them on the street, commanding them to appear at the test station within three days. The motorist thereupon brings his car in, his headlights are tested, and

if he is found wrong, he is handed a pamphlet and told to fix up his headlights himself, or visit one of half a dozen or more approved service stations. These service stations secure their official approval by demonstrating their fitness by sending in to the test stations half a dozen cars properly equipped. Also the results of their work are checked by the department when the motorist comes back, after having visited a service station, for a final check; if the service station has not done its job well it appears when the test is made.

This is the best testing scheme with which I have had experience, for getting compliance with the headlighting laws, but in Wisconsin it has been tried in only one city. Whether or not we can get stations in our other cities is problematical. The difficulty lies in the fact that cities do not have illuminating engineers in their employ and there is no standard test boards available. Each town would have to build its own board, and would require the services of an illuminating engineer.

Enforcement is so vital to the success of the headlight laws that I think the Committee should now turn its attention to it. Some standardized testing method universally employed has the same merit as a standard law for all states. I think it is incumbent on the Committee to help the states to find the best enforcement method and when it is found energetically to urge its adoption wherever the I. E. S. specifications are in effect.

F. C. Caldwell: The automobile headlight situation in Ohio at present is in an acute state. We look upon Massachusetts as a pioneer and hope that some day that Ohio may be able to do the same; probably, however, the conditions in Ohio correspond more closely to those in most other states.

Ohio has a law which went into effect in August. It was a peculiar situation; a self appointed committee was working on a law, and hoped to have it presented to the legislature. Before the contemplated law was dropped however, it was found that there was a law already introduced. It did not seem well to complicate matters by introducing another, so, although the measure before the Senate was not altogether satisfactory, its passage was encouraged. Curiously enough, the origin of this law seems to be something of a mystery.

The Ohio law calls for the use of approved devices which will give road distribution with adequate driving light at two hundred feet and avoidance of dazzling rays. It provides for the testing and approval of devices by the director of highways of the state. It provides that not more than thirty-two candlepower shall be used in the lamps. It also provides a penalty, but has no provision for enforcement other than the ordinary police power of the state. This is where the law is weak as compared with the laws of Massachusetts and Connecticut, but it corresponds to the conditions in many other states.

The Director of Highways is a civil engineer who has a big program of road improvement on his hands, and he did not know anything of this headlight law till it was on the statute books. He naturally is not greatly interested in it. He was persuaded that the only way in which the law could be properly executed was by having a committee draw up regulations to interpret the more or less indefinite law. At his request, a group of five citizens, none of them commercially interested, was gathered together and the I. E. S. regulations, with slight modifications, were adopted. The only notable changes are that the tests are made with 21-candlepower tungsten lamps only, and also that the "number two" test calls for the use of two headlights with 21-candlepower lamps.

The testing of the headlights was assigned to the Engineering Experiment Station of the Ohio State University. The present status of the matter is that there are comparatively few cars on the road in which there is not some special headlighting equipment. In many cases, it is the home-made device, and of course, many are Fords. There are quite conflicting reports as to the present condition. Mr. Magdsick has told me of a drive between Cleveland and Sandusky during which he passed five thousand cars; his observation led him to believe that the conditions are a great deal better than they used to be. On the other hand, one hears some contrary reports from less careful observers. The problem before us is to get the people to understand that they must adjust the devices on the cars, and we are convinced that, as has been said by the previous speaker, this can only be done

through testing stations. There are no state funds in Ohio, available for any kind of effort along this line. The matter was left by the legislature in the hands of the police.

Fortunately, however, certain commercial interests are taking this matter up along broad lines, and are meeting with considerable success. They are trying to educate the people as to the need for proper headlighting without emphasizing any particular device. This is notably so in Cincinnati and Cleveland, where the automobile clubs have been persuaded to co-operate with the police and to arrange for certified testing and adjusting stations in a large number of garages. In Cleveland, one of the companies has set up an equipment on a side street and has arranged with the police to send automobiles onto this street, giving an opportunity to show drivers what good distribution is and how badly their headlights match up with it.

There are one or two points with regard to the I. E. S. regulations brought out by our experience, that I would like to mention. In the first place, with regard to the tilting headlight,—as was indicated in Mr. Magdsick's paper, there is a demand for more light in the case of rapid driving than the I. E. S. specifications provide for. Our law has been interpreted up to this time, as providing that if a device meets the specified distribution in any definite position, it complies with the law. It has also been required, in order that a device shall be approved, that it shall have only two operating positions, and that these shall be definite. Thus a tilting headlight may be approved for the down position regardless of what it does in the up position. It is then necessary for the driver to take his chances if he uses it in the up position, just as he would if he drove his car at fifty miles an hour. If he gets into trouble, he has only himself to blame.

The importance of one of the points mentioned by Mr. Devine should be emphasized; namely the great difference between laboratory and road tests, I believe the I. E. S. specifications should recognize this difference and that there should be a factor of considerable magnitude to account for the loss of candlepower due to conditions inevitable on a car. Another point has to do with the prevention of glare at the right side. We felt that consideration for the eyes of the pedestrian coming along the walk on the right side of the road requires that he should not have more

than eight hundred candlepower in his eyes, and I believe that the specifications should be modified to provide for this. I agree with Mr. Devine that it would be desirable to have striations more definitely mentioned in the specifications. This point is also brought out in the paper of Messrs. Magdsick and Falge.

D. A. FEIGLEY: I think we all should interest ourselves more with what happens to the average motorist after he receives the Society's recommendation. I believe the Society and the people who are following the Society's recommendations receive a lot of unfavorable comment because of some things which we are unable to explain clearly so that the average individual knows what we are talking about. That is the trouble we find in the lens business through any of the states that have accepted the I. E. S. specifications.

I would like to refer to an article from an Ohio paper headed "May Ask Lens Law Repeal." It states that there is considerable confusion and conditions are no better than before, and, therefore, asks why such a law should be on the statute books. Certain interests are accused of having the law passed. We all know that the law is good, but as to how it can be applied for the public, should be our next concern.

Mr. Devine, in Massachusetts, brought out and distributed in all sections of his territory a device which has helped the situation. In the first place, there were five points hammered at the public until they began to know that buying a device didn't mean very much but what they did with that device after they bought it was of greater importance. The card which Mr. Devine issued had very clear instructions.

There was a paper submitted to the Society by Professor Grondahl, Director of Research in the Union Switch and Signal Company, (TRANSACTIONS Aug. 30th, 1921,) which describes a device similar to Mr. Devine's card, but provides a combination of focusing card and lens which obviates the necessity of removing the headlight lens to prove whether or not the device is properly focused.

I believe that ultimately something of this sort must be used with all lenses if we take into consideration that the manufacturer's instructions on lenses to-day do not apply in eighty per cent of the cases. I say eighty—I am guessing—but I be-

lieve you can form your own opinion as to the percentage. For the devices that take a number one focus, the individual is instructed to bring the spot to the smallest cross section possible without the device on. But most of the lenses, (Fords, for instance), are adjustable from the back by means of a screw and the reflector is held there by a spring, which means that as soon as you put the device on the car your reflector is sprung out of position and the result is that your lamp is immediately out of focus.

I think that something that should be taken care of in future laws is to have the manufacturer put out instructions which really can be followed and get some results. I believe the adding of such a device as Prof. Grondahl explains in his paper, will help the situation because with it the focus can be proved after the device is put on the lamp.

LOUIS BELL: Mr. President and Gentlemen, I have been tremendously interested in this discussion and there are one or two high spots in it I would like to mention. One is the very interesting work done by Mr. Magdsick, especially with respect to the great difference in light required at various car speeds. It looks very much as though at the high car speeds there has to be a compromise between the speed fiend and the law, with the weight of evidence on the side of the law, because at forty or fifty miles an hour the light required above the line dangerous to both driver and pedestrian becomes excessively great. We must not forget the pedestrian. We can't expect the pedestrian to carry a red tail-light as the British Tommies used to in marching in column formation just before the war.

It is necessary for success that we have good headlights, well-made headlamps; that they should have proper focusing adjustments and that the lamps, the bulbs themselves, should be somewhere near uniform, and that the makers adhere to one size and shape. Any change in the length of the filament, the shape of the filament, or the position of the filament has profound effect on focusing. These things have an effect on the distribution of the light produced by a given parabloid, and have a very great effect on the spread of the light. There should be an agreement on this point.

As regards the point raised by the last speaker it is certainly true some headlamps are very hard to adjust, of course; as a matter of fact, the two-hole device that Mr. Devine shows allows a good many of the prismatic reflecting devices to focus through the lens without any special facilities, but anyhow it is desirable to have a headlamp so arranged that it can be focussed readily.

I think we must come down to a standardization of bulbs, to a standardization of the dimensions and focus of reflectors as far as possible and particularly to furnishing adjustments which can be readily adjusted in focussing the lamps.

Dr. G. S. Crampton: I just want to say a word I didn't get a chance to say last night when we were occupied with the subject of cold light. I would like to pose as a pioneer in the use of cold light in automobile headlight work.

During my service abroad I was inspecting one of my field hospitals in the Argonne Forest the night before our big barrage. The outfit was in a partially underground structure as near the front as we dared to place a field hospital and the one road leading to the rear was jammed that night with every sort of mobile war material imaginable, not to mention troops who were threading their way forward among the caterpillar gun mounts and other things cn wheels.

The road which was overshadowed by trees was extremely dark, and as I had occasion to inspect another hospital to our rear I was at a loss to know how I was going to buck the oncoming stream. Of course as usual all lights were taboo. However, by a piece of rare good luck just as I was starting for my Dodge I kicked into a mass of chips lying about the base of an old stump. They loomed up like coals of fire so taking the hint I filled my lamps with them and with a few large pieces in my hand I walked ahead about twenty feet and guided my chauffeur through the thickest of the traffic.

E. Y. Davidson: I think Mr. Devine is to be complimented for his work in Massachusetts. Being somewhat familiar with the lighting legislation movements in several states, I know it takes a lot of nerve and pluck to put through a campaign of the nature Mr. Devine has undertaken.

Professor Caldwell has told you something about the Ohio situation. I have been working in that state for the last ten weeks endeavoring to teach motorists at large, police, jobbers and dealers how sixty-two approved devices in that state should be focused and aimed. Work has already been done in Cleveland, Cincinnati, Toledo, Akron, Ashtabula, Youngstown and Warren. In almost all these towns the work has been received enthusiastically and headlight focusing stations have resulted.

In Cincinnati garage owners wishing to establish a focusing station have been instructed by two engineers working through the Automobile Club. These warranted focusing stations are empowered by the Chief of Police to issue certificates showing when the adjustment was made, the name of the owner of the car, the make and model of the car, the name of the approved device, the name of the focusing agent and the candlepower of the lamp used.

In Toledo the city has established an official headlight focusing station. At this station every motorist in town is expected to report. If after he has reported it is believed by the officer of the Police Department that his lenses are focused correctly, he is issued a certificate to that effect which he is to carry and exhibit upon demand by a traffic officer. If his lamps are not in adjustment he is given a blank form and told that he must have his equipment properly adjusted by a competent agent officially recognized, and report back to the first mentioned station within ten days. If he reports within that time and it is found that his equipment is satisfactorily focused he is issued an approved certificate. If the work by the focusing agent has not been satisfactorily performed he is sent back. If the motorist does not return to the official focusing station within ten days the Police Department goes after him and brings him back at some time not of his own chosing.

One word about the difficulty in undertaking such work— In many towns the officials fight shy of our offer to help them with their problem because they cannot believe we are willing to undertake the work from an educational standpoint only, introducing no advertising or sales propoganda. In Cincinnati the most stubborn opposition was encountered until a clipping from

the Washington *Star* was shown which stated that the Bureau of Standards had made public a statement that every up-to-date town of any size or consequence must in the future incorporate in its municipal equipment means by which automobile headlights can be focused and adjusted. This was published under the direction of Mr. E. C. Crittenden. The minute the authorities saw this article they began to realize that other people were thinking and talking about the same things we were. They mimeographed it, published it broadcast, and gave us every opportunity to carry on the work we had originally planned.

I think the Committee on Motor Vehicle Lighting is to be congratulated on the way in which they have handled their problems. They have had their hand upon the pulse of the motor-driving public and have gone just as fast in their stiffening of the requirements as automobile owners would allow. They have not excited adverse criticism which would tend to stifle the good work they have yet to do. I think, however, that they, in the future, should recommend the adoption of 21-candlepower lamps in the certification of approved devices in several states, and the elimination of the maximuum and minimum candlepower permitted in the approved devices. Such candlepower ratings are interpreted by the laymen to be the measure of the excellence of a given device. We know that this is not as it is intended, and that it merely shows to some degree the performance of the device in its relation to the maximum allowable candlepower at the glare point "D." I believe also that in the future it would be well to consider the establishment of a minimum candlepower requirement for points on a line passing through C and D. We realize that a perfectly sharp cut-off is undesirable. If no light were given above the horizontal, a buggy on the right hand side of the road would look to the moderately fast driving motorist as though it were two sticks widely separated, because he would only see the end-on view of the two rear wheels. Boughs and obstructions from above could arch over the roadway without being observed. It seems to me that if more than 400 candles or less than 800 candles were required at the glare point, we would take a forward step.

F. H. Ford: I wish to express my appreciation of Mr. Magdsick's paper. It is of particular interest and value since so far as I know there has been no published data in regard to the light distribution desired by the average driver.

On the matter of test stations, I agree with Mr. Hoeveler and Prof. Caldwell that the test station seems to be one of the most important factors in the solution of the problem of securing compliance with headlight regulations; at least so far as the larger cities are concerned.

However, at least in the central and middle western states by far the largest percentage of cars will be found in cities and towns of less than 15,000 population and these towns cannot afford to install or operate expensive test stations such as the one in Milwaukee which Mr. Hoeveler described.

I think that the Committee on Motor Vehicle Lighting could render a great service to the public if they would figure out some kind of a simple test board, not using the illuminometer principle as is the case of the Milwaukee board, which could be set up in a vacant lot or at the end of a street where drivers could check their own lights.

It would seem that it should be practical to design such a board using some such a device as a broken circle or groups of parallel lines so proportioned as to be clearly distinguishable under one intensity of illumination but not clear with a lower illumination. Of course such a screen would not be accurate but if it could be designed to indicate within 30 per cent of the actual values of illumination it would be good enough for practical purposes in giving drivers who wish to comply with the headlight regulations the means of at least trying to do so.

While the Illuminating Engineering Society is not directly interested in the enforcement of headlight laws the invaluable work which this Committee has done can not accomplish the result it merits unless the work can be carried further through suggesting some simple means by which drivers can themselves tell whether or not their lights meet the specifications which the committee has suggested.

G. G. Cousins: There are two conditions that operate to render ineffective the good work in testing that is being done.

These are, that several lenses, approved as quite satisfactory optically, are soon twisted from their proper positions by the vibration of the cars, no means being provided to maintain them in a definite position, and that many headlamps are too flimsy in construction to hold the lenses rigid.

The standardization of a few mechanical details would do a lot toward the elimination of this evil, and the influence of this Society might assist in the accomplishment of the necessary standardization.

L. C. Porter: I would like to say a word in appreciation of Mr. Magdsick's paper. I have had the privilege of riding two or three times in that car and the investigation is certainly most interesting. Mr. Magdsick pointed out that for higher speeds *i. e.*, above forty miles per hour, the average person wanted higher intensity. In some of the work we have carried on, we have found in city driving a fairly wide beam was desirable, but when we get out into the country and drive at higher speeds, light on the side of the road has proven objectionable to some.

So far, all the regulation and control of headlighting devices has been put up to the car owner. I believe the Ford Motor Company has recently made a move which seems to me good, and which could to advantage be followed by other car manufacturers. I don't know whether this is general or not, but in the State of New Jersey the Ford agents are required to have painted on their garages or wherever they sell their cars, a white rectangle about three feet wide and two feet high, at a distance of twenty-five feet ahead of the car, and every new car is required to have the headlights adjusted so that the rays come within that space before it is sold. It seems to me that is a good thing, and if other car manufacturers were compelled to have their agents see that some such adjustment be made on every new car sold, it would help the situation a good deal.

There is one point which Mr. Devine did not mention in connection with work in Massachusetts which I think is interesting. He is attempting to control the beam more or less by controlling the size of the light source, and I understand that he contemplates limiting the voltage of the incandescent lamp which will be passed to maximum of twelve to sixteen on the theory

that lamp filaments of higher voltages than that are so much longer that the beam cannot be controlled.

I think it would be interesting if Mr. Magdsick would explain that for us.

C. H. SHARP: The discussion of this subject has proceeded very largely along lines with which the Committee and the Society haven't very much to do. We are an illuminating engineering society. We are not a society of automobile manufacturers, headlight manufacturers or lamp manufacturers or state officials. We are trying to do things solely from an illuminating engineering point of view.

Now, all these other things go along with it, and we are all very glad to see these evidences of keen appreciation of the necessity for enforcement of these regulations, and to learn the means that are being taken to insure such enforcement, and I am sure we are all gratified to see the seriousness with which the question is being considered.

Someone said something about the Committee being able to reject a device. Of course we cannot accept or reject anything. We have written illumination specifications and that is as far as we can go. It is true that some devices which are mechanical or optical monstrosities pass the illumination specifications. That does not mean that they ought to be accepted. Something besides the illumination yielded in a laboratory test must be considered. These are cases where the illumination specifications alone are insufficient and where the state authorities should refuse approval even though the illumination test is satisfied. The Illuminating Engineering Society, however, cannot, because of the limitations of its field, take cognizance of such cases except to the extent covered in Section V of the Specifications.

I want to say a word about Mr. Magdsick's report. Mr. Magdsick is doing pioneer work. He is looking forward to showing what a headlight beam should be. It is work along right lines and I hope that a great deal will come out of it, and a great deal which eventually this Committee can incorporate in improved specifications as standards of desirable practice, to be turned over to the S. A. E.

Mr. Devine is making a very interesting experiment for us in Massachusetts. He has put some different points in his specifications. He is obliging automobilists to spread the light out sidewise. Our Committee felt that it was a doubtful question whether the State should tell automobilists what kind of a beam they ought to have, provided it was a safe beam; and we did not venture as far as Mr. Devine has. Very likely Mr. Devine is right. At any rate he is making the experiment and the great State of Massachusetts is the experimentee, and we hope a great deal of good will come of it. The price which is paid for this experimentation is that he has deviated from interstate uniformity and standardization. However, if we don't vary some time or other, we are not going to advance, so we are grateful to Mr. Devine for going ahead and finding out what happens when we depart slightly from the straight I. E. S. specifications.

H. H. MAGDSICK: Most of the observers expressed a positive objection to a very wide beam of light because of the distraction caused by the bright vertical surfaces of the weeds and grass on either side of the road. They preferred to suffer the inconvenience of having rather insufficient illumination at the sides under certain conditions encountered less frequently. The objection to the wider spread of beam was raised particularly at the higher speeds, as is made evident in the test data. Some observers would turn out all light near the car when traveling in the higher speed ranges, so as to improve visibility at greater distances; they probably found no practical importance in being able to see objects within 20 to 40 feet of a fast moving car.

As between a form of beam with sharp cut-off and maximum intensity at the top illuminating the road far ahead and to a relatively uniform brightness; and a beam with a more gradual intensity gradient requiring that the highest intensity be directed to the road surface somewhat nearer the car but also giving relatively more light above the horizontal; the observers almost invariably chose the former. At the same time they recognized that they were somewhat handicapped with the first form of beam with very little light above the horizontal. It is of course possible to combine in a headlighting equipment the advantageous features of the two forms.

A. W. DEVINE: I believe there has been only one question raised about the lamp, and that involves our method of enforcement. Now, our law is drawn to get the results by condition of equipment and adjustment, and such being the case, it is necessary to define the particular conditions under which each device can be used, and define them completely. For instance, one condition is the minimum size of the front glass and reflector; another condition is that under which the device shall be installed. A third condition is the size of lamp bulbs and that is the condition which Mr. Porter asked particularly about. We didn't feel, without a special test that we could approve of any of these devices on account of variations in the size of the lamp filaments and shapes of filaments, except for use with gas-filled bulbs of no more than twelve to sixteen volts. The eighteen, twenty-four volt and larger bulbs may not, therefore, be used unless a special test is made on the approved devices. It will be necessary then, for anyone who has, for instance, a nine-cell battery to put in nine volt bulbs in series.

The specified limiting intensities of the Massachusetts specifications and the Society specifications are meant to define a beam which will give a safe road illumination for driving at moderate speeds and under normal conditions of visibility.

Many devices which comply with the limiting intensities do not comply with the intent of the specifications because of unduly dark or bright areas within the region covered by the specified points.

It seems to me that the Committee on Motor Vehicle Lighting might well define under what conditions such dark and bright areas in the beam are unsafe.

An analysis of 400 serious accidents in Massachusetts in 1921 shows that about 15 per cent of the night accidents are due to insufficient light, and about 5 per cent are due to dazzling lights. This clearly shows the necessity for securing a safe driving light, and a proper definition of an unsafe beam as mentioned above.

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THE LIGHTING OF PUBLIC BUILDINGS*

BY A. L. POWELL** AND EDGAR PARKER.

INTRODUCTORY

Before the art of illumination had reached its present day importance, the illuminating engineer might have been compared to a physician—he was called in to prescribe a remedy only after conditions were bad enough to cause discomfort. A careful survey of lighting installations in our public buildings reveals many instances which serve to illustrate this back-handed method of attacking the problem.

A thoroughly satisfactory building really depends upon the preliminary planning of the lighting simultaneously with the structural elements, and as public buildings in general are elaborate structures with special lighting requirements, the best results are obtained only when these features are carefully considered beforehand. For example, adequate space should be available for lamps and reflectors above ceiling-windows where such lighting is employed; flexible control and a sufficient number of circuits to take care of future demands should be provided for; and convenience outlets at frequent intervals to meet particular conditions are all factors worthy of preliminary consideration.

Our public buildings represent a considerable investment for the education, protection and enjoyment of the people, and in order that the privileges tendered by these buildings may be utilized and that the interior may provide comfortable conditions for those employed here, it is of the utmost importance that adequate lighting be provided.

* A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26–29, 1921.

**Lighting Service Dept., Edison Lamp Works of G. E. Co., Harrison, N. J.

THE LIGHTING OF ART GALLERIES

Proper lighting of the art gallery is both an important and interesting subject. The buildings themselves often represent a large expenditure and are more or less monumental in character and dignity, and consequently require artistic and harmonious lighting. In the second place the priceless collections of paintings and sculpture exhibited here must be well lighted so that the public may view and study them in comfort. And third, in order that the works of art may be presented so that the details will stand out as the artist conceived them, there must not only be ample light, but direction and color values must be carefully considered.

The logical arrangement of the paintings is to place those of a dark nature at the top, for with predominant light from above the higher intensity will naturally be on the paintings which require it. We see by reflected light, and when this fact is considered, it at once becomes apparent that by this arrangement a more uniform and attractive gallery is the result.

The background, or walls, should be of neutral tone, non-glossy in character and of low reflecting power, so that reflections from the walls are eliminated and there is consequently nothing to distract the attention from the exhibit. The neutral tone is of special importance, as a brilliantly colored background may reflect enough light to modify quite materially the color value of the paintings. For example, a red background was used in the Tate Gallery in England, and its selective reflection distorted the color of some of the finest Turner paintings.

Two general methods are commonly employed in the illumination of galleries—one where the lighting is accomplished from the sides, and the other where the direction of light simulates actual daylight conditions and comes from overhead. Whatever system is used, the intensity should be sufficient to illuminate the dullest piece in a collection, and care should be exercised to see that specular reflections from the painted and glass surfaces are minimized. The reader has often had the experience when viewing a collection of being annoyed by a multiplicity of reflections which distract greatly from the interest of the exhibit.

This condition is most frequently encountered where the side system is employed as evident in Fig. 1. Here the paintings are represented as illuminated by lamps in a continuous trough reflector, and the light rays are indicated by the broken lines. The collections are usually viewed from the area between A and B, and eye level is shown by the dotted line. It can readily be seen from the sketch that any slight divergence of the fixture from the correct position, will cause the light rays to be reflected into the area from which the paintings are viewed, causing annoying specular reflections.

Both individual and continuous units are employed for the

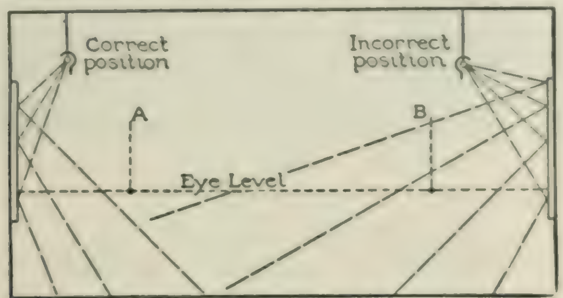

Fig. 1.—Section of a painting gallery, showing how an incorrectly placed fixture may result in annoying specular reflections.

side lighting system. It is evident that whatever type is utilized, the principles outlined in the above paragraph should be adhered to and careful design or experimentation is essential before the final installation is made. Even where individual units are employed, it is generally desirable to conceal these from view by a suitable screen or framework of metal or other material.

Mirrored glass offers certain advantages in the flexibility of control of distribution, but plain or smooth mirrored surfaces should never be employed on account of image reflections. For temporary installations, white paint enamel gives excellent results from the standpoint of reflective properties and diffusion, but for permanent installations, it is quite out of the question, as it turns brown from the heat of the lamp, blisters and peels as well as accumulating dust and thus having its reflecting power considerably lowered. The exterior finish of the lighting equipment and supporting mechanism should be neat and harmonious with the room decorations.

The number and size of lamps to employ will depend on the character of the exhibit and should be determined from experiments. For ordinary conditions, from 40 to 60 watts per running foot of wall will provide an intensity of approximately 6 ft.-c. on the picture. A night view of an art gallery with a typical side lighting system is given in Fig. 2. A continuous trough reflector, with rippled glass strips so placed as to give the desired distribution of light, is used.

It is certainly desirable, when the construction of the building permits, to utilize an artificial sky-window* as a means of illuminating paintings, for not only can a better lighting effect be obtained, but the appearance of the room without fixtures is much more attractive (Fig. 3.) Here the lighting installation is placed above the ceiling and a uniform intensity of 6 ft.-c. is obtained upon the walls. Sixty-watt tungsten lamps in porcelain enameled reflectors are placed on 3-ft. centers and suspended 18 in. above the glass ceiling. These lamps are supplemented by 40-watt tungsten lamps, spaced 14 in. in a trough reflector, placed at the edge of the sky-window and directed to throw the light towards the walls, thus keeping the horizontal and vertical components of the light nearer equal. The room presents a very attractive appearance and the uniform illumination of the glass in the ceiling is worthy of mention. The glass itself is of such a nature that the lamps or overhead construction cannot be discerned from the room below.

In a system of this type, the hanging height of the units above the ceiling will depend upon the wattage of the lamps used and upon the glass in the ceiling. The lamps and reflectors should be so arranged that the glass presents a uniform appearance from the room below, and the glass itself should be of such a nature that the lighting source cannot be discerned. Some excellent data on this question have been presented by Mr. E. J. Edwards before the Illuminating Engineering Society. (See the Appendix—Bibliography.)

One method of installing a lighting system above the ceiling is shown in Fig. 4. Here 60-watt tungsten lamps in porcelain enameled reflectors are placed on 3.5-ft. centers, 18 in. above the stippled glass window. The close spacing of the steel

*The editor has substituted the term "sky window" for "sky-light" which appeared in the authors' manuscript.

Fig. 2.—A night view of a well known painting gallery illuminated by 40-watt lamps in a continuous rippled mirrored glass reflector. The lamps are spaced on 12 in. centers and produce an intensity of 6 ft.-c. on the paintings, without image reflections in the line of view. The moon renders the over-head window luminous.

Fig. 3.—The attractiveness of this painting gallery, illuminated from above the sky window, is apparent at a glance. Data on the installation are given in the text.

Fig. 4.—A view showing the arrangement of reflectors and draw curtains above the ceiling of a painting gallery. Here 60-watt lamps are used 18 in. above the glass on 3-ft. centers.

Fig. 5.—A night view of the foyer of a museum showing the pleasing effect obtained by using diffusing bowls. Three 75-watt lamps are used at each outlet which are on 16-ft. centers, giving a uniform intensity of 4.5 ft.-c. throughout the foyer.

girders in the structure necessitates the use of low-wattage lamps.

Where the space between the windows is not obstructed by the steel girders, higher-wattage lamps, spaced further apart and at a higher distance above the glass, are advisable. Angle units so suspended as to direct the light on to the opposite wall are preferable to reflectors giving a symetric distribution of light on account of their higher vertical components. Examples of their use are noted in the references.

Another factor which requires consideration when the gallery is equipped with a ceiling window for admitting skylight, is the continually changing quality of daylight so that some system or method of modifying the intensity should be provided for. This may be effectively accomplished by installing a system of adjustable louvres between the sub-skywindow and the main skywindow. The louvres may be of metal, or may be of cloth on wooden frames, and in either case they should be controlled either pneumatically or electrically, from the room below. Thus, when the sun is in such a direction as to light one wall to a higher intensity than the opposite, the attendant may adjust the louvres until more uniform illumination is obtained.

A much simpler method, as shown in Fig. 4, is to provide a large draw curtain between the two skywindows which can be drawn across when the intensity is too high. This system is, of course, less expensive, but is not as satisfactory or flexible as the former.

The question of proper color quality of artificial light for an art gallery can be viewed from many angles. All of us know that a distortion of hue results when lights of different spectral characteristics fall on colored objects. This is true even in daylight. One artist, for example, noted that his blues were never as vivid in the finished picture as when he mixed them on his palette under the open sky by the seashore with the bluish skylight as a factor.

At the other extreme, are all our common light sources which are rich in the red and yellow, making distortion even greater than with variations of natural light. That this fact is not fully appreciated, is apparent, for one prominent artist is recorded as saying that the color of artificial light was of no importance as "a work of art is a work of art under any conditions."

From a theoretical standpoint in displaying a painting, it seems most logical to attempt to reproduce conditions under which it was conceived. A picture painted by daylight obviously transfers the artist's conception best under natural light, while those painted in artificial light should have similar treatment.

In an art gallery, however, all types are found in the same group, and even the position of individual works may be changed from time to time. It is scarcely expedient to be constantly shifting the lighting.

It is probable that the majority of pictures were produced under daylight conditions and the daylight (blue bulb) lamp seems to be a legitimate light source for the art gallery. It is a compromise between unmodified artificial light and average daylight, sufficiently efficient to warrant its use. When lamps of this character are used, the transition at nightfall is much less noticeable.

There is another phase of the question which is not generally applicable to the large gallery and possibly open to objections on the part of the true connoisseur, that is, special lighting by tinted lamps of individual pictures. Many paintings appear to better advantage when so lighted. Certain colors or tones may be accentuated or subdued with skillful treatment. Again, each picture may be illuminated by light with a certain predominating direction, coincident with the general direction of light in the picture, thus heightening the contrast. This field of lighting presents many varied and interesting problems, and in general, needs specialized study for each individual work. A rather complete discussion is given in one of the references cited.

For mural and ceiling paintings, similar requirements, as to uniformity, color and intensity, as those encountered with pictures hanging on the walls are presented.

With decorated ceilings, unless structural details are such as to cause a suspended indirect unit to be in good taste, the side system, that is, trough or cornice, offers the happiest solution. Cornice lighting obviously requires very careful design to avoid spotted effects or specular reflection, and since the lighting units are inverted, proper maintenance or cleaning is a very important element.

It is apparent we cannot readily reproduce the equivalent of the top lighting system, although the ceiling in one of the buildings at the Panama-Pacific Exposition was illuminated by search-lamps placed below the plate glass floor; with ingenuity, similar results can be secured in a less expensive and effective manner.

A novel installation of this character is to be observed in Gallery No. 32 at the Metropolitan Museum of Art, New York City. In a room about 20 ft. square, are installed a series of 22 ceiling paintings by Picturrichio, from the Plazza Del Magnifico in Sienna. The attempt was made to show them in a direct reproduction of their original settings. The architectural construction of the room prohibited the use of cove or cornice lighting, and ceiling units would obviously be unsuited. The lighting equipment was placed outside the six cathedral glass windows, located three on a side on opposite walls. Each is about 4 x 6 ft. and three 100-watt type C lamps without reflectors, are symetrically placed at the rear of the glass. These are supplemented by a row of 25-watt tungsten lamps on 9-in. centers in a mirrored glass reflector at the bottom of the window. The total power consumption is approximately 4 watts per sq. ft. of floor area.

Natural light enters through exterior windows and then passes through the art glass panes mentioned above. At night a shade is drawn between the two windows, which acts as a reflecting and diffusing surface. The resultant light is soft, comfortable and effective. The intensity on the ceiling is about 1 ft.-c.

LIGHTING OF STATUARY

The sculptor may choose the most perfect piece of marble and model it into a sublime work of art; a perfect reproduction of his inspired vision, yet a careless arrangement of the work with reference to predominant light may cause unseemly distortions and a shattering of the expressed ideals.

The beauty of statuary lies in the relation of high lights and shadows. The desirable density, sharpness and quantity of shadows, depends upon the emotion to be depicted. Tragedy demands sharp contrast and bold shadows, as exemplified in the Loacoon group. On the other hand, a piece of work similar to

Aphrodite, portraying soft, subtle modeling, and a face of radiant pleasure, needs a softer light to bring out the effect of the more quiet emotion. Shadows are troublesome in sculpture only when they tend to produce false impressions.

Under artificial light, the degree of shadows produced depends upon the type of unit used. If a direct lighting system is employed, the sharpest of shadows are produced with little diffusion, except from the light reflected from surrounding surfaces, such as walls and floors. With a totally indirect system, of course, a minimum of shadows is obtained, and this lighting is scarcely of service. With semi-indirect units, however, we have a particularly fortunate condition. The proportion of direct to diffuse or reflected light is dependent on the density of the glass of the bowl or with a given density of glass, these factors can be varied by tinting and toning the ceiling, increasing its absorption. Enclosing or semi-enclosing diffusing units having similar properties are also useful in producing a suitable combination of direct and diffuse light.

A systematic arrangement of either of these two latter types of units, providing an intensity of from 4 to 6 ft.-c., gives good results. Since a greater amount of direct light is usually produced immediately beneath the outlet, it is quite logical to locate objects requiring well defined shadows in such positions and those of "softer" lines in the more diffusely lighted areas.

Thus, artificial light, on account of the possibility of readily changing the intensity, color and direction, is one of our best mediums of artistic treatment. Crude, stagey effects should be avoided and one must realize that while lighting cannot make art, it can certainly mar it.

LIGHTING OF MUSEUMS

Our museums contain priceless collections of natural, scientific and literary curiosities, conveniently exhibited where the public may view and study them at leisure. It is important that the specimens be arranged and displayed to their best advantage, and this can not be accomplished unless the exhibit is properly illuminated to facilitate careful study.

There must obviously be good general lighting, special lighting of a high intensity for small objects in show-cases, and more or less stage lighting effects where a group is presented in its natural setting. Proper lighting will do much to render the building attractive, stimulate interest and assist in serious study.

Glaring light sources and reflecting images must be avoided, for there is no one factor which tends to reduce the effectiveness of a museum more than annoying reflections in the glass surfaces of the cases. A well diffused, general lighting is required, of an intensity of 6 to 8 ft.-c., so arranged that it will not cause objectionable shadows on the exhibits. The indirect systems, or diffusing direct lighting units of neat simple lines, meet these demands. The fixture itself should be dignified and in conformity with the architecture of the building. In the foyer and similar places, massive ornamental standards or multiple unit fixtures are frequently necessary to carry out the decorative idea.

The lighting of exhibit cases is obviously an important feature. In general, they may be divided into two distinct groups—those constructed entirely of glass and readily illuminated by the general system, and those having an opaque top, or of such a nature as to require local illumination. The principles applicable to store-window lighting are effective here. The wall cases usually have a cornice at the top behind which lighting equipment may be readily installed in an inconspicuous manner. As most of the cases are air-tight in order that they may be dust proof, it is important that low wattage lamps be employed to prevent excessive heating. Small mirrored glass or metal individual reflectors or continuous trough equipment can be utilized. The type of light distribution given by the selected reflector will naturally depend on the dimensions of the case.

It is interesting to contrast Figs. 6 and 7. In the former a lighting installation carrying out the principles outlined above is in service. Relatively high wattage type C lamps are employed in neat semi-indirect bowls of medium density. The diffused light makes the room comfortable, illuminates the exhibits effectively, showing up the mural paintings to good advantage and eliminates annoying reflections from the table and wall cases. In. Fig. 7, the educational value of the priceless collection of

birds is very materially reduced by the ineffective lighting which exists, even at this present day of widespread knowledge of the principles of illumination. Multiple unit bracket fixtures with bare carbon lamps are attached to the high glass cases. The direct glare is, of course, serious, but numberless reflections, far more annoying, are to be seen in each pane of glass. How much more attractive this room would be with a moderate intensity of general lighting from overhead units and concealed lighting within the cases themselves.

As mentioned above, the most interesting phase of museum lighting is that of providing special effects for cases or alcoves containing objects in their natural surroundings. The principles of stage lighting have been applied to the show window with excellent results. They are especially applicable here. The method of handling individual exhibits will depend on the construction of the case and the ingenuity of the designer. Figures 8 and 9 present two typical examples. In the former, a North Florida group, showing birds and reptiles in characteristic attitudes, the top of the case is of diffusing glass. Above this is located a row of 40-watt tungsten lamps in bowl type reflectors along the front edge of the case. In another position is placed a group of 100-watt lamps in concentrating reflectors, directed so as to give the appearance of sunlight streaming through the foliage.

In Fig. 9, several Hopi Indians are busily engaged in their daily household tasks. The old man in the background casts a dense shadow behind him. The foreground is in comparative darkness, while the village itself is brilliant with the noonday sun. Twenty-five watt tungsten lamps in bowl shaped reflectors carefully concealed from view illuminate the general scene. A 250-watt concentrated filament lamp in a small lens spot directs the beam of light as indicated by the shadow effects. Color and direction of light are again of service in conjunction with experimentation.

The laboratory and workshops of the museums (where figures of the groups are cast or modeled specimens mounted, magnified copies of objects made in glass and wax, and models of all sorts repaired) offer no distinct problem from those of the

Fig. 6.—The effective illumination produced by a semi-indirect system is well shown in this night view of an exhibit room. 300-watt lamps in opalescent bowls on 16-ft. centers provide an average intensity of 7 ft.-c.

Fig. 7.—An old style carbon lamp installation still in service. The annoying reflections and glaring conditions distract greatly from the appearance of the room.

Fig. 8.—A view of a Northern Florida group depending entirely upon the artificial illumination for the lighting effect. The lighting is accomplished by 60-watt lamps in steel reflectors placed above the opal glass top of the case.

Fig. 9.—The night view of an alcove containing a Hopi Indian group shows the effectiveness of skillfully applied artificial light. The principles of stage lighting are directly applicable to such displays.

ordinary industrial plant with similar demands on vision. A high intensity of general illumination with efficient direct lighting units, such as standard dome reflectors and bowl enameled type C lamps will permit accurate work amid pleasing surroundings. Convenience outlets to which suitably shielded local lamps can be attached are necessary along the benches in order that the very high intensity, necessary when working on minute objects, can be available.

The reception rooms, corridors and offices, present no questions distinct from those of similar rooms in other classes of service. These fields of lighting have been discussed many times and need no further attention at this point.

LIGHTING OF LIBRARIES

The use of a library reflects to a greater or less degree the intellectual and artistic standing of the community, and there is, perhaps, no better way to invite patronage than by making the interior attractive and comfortable. Even though the building is beautifully designed and well provided with books, unless the lighting is suitable and adequate, it is not a thoroughly effective institution. The primary function of the lighting installation is to enable printed matter to be read with ease, but in addition, it offers an opportunity for accentuating the architectural design and beauty of the building.

Libraries may be divided into two quite distinct classes—one, the monumental building of the large city where the rooms are spacious, ceilings high, corridors handsomely finished in marble, and where the element of decoration plays a large part. Reading rooms in this class of buildings are generally separate from the stack room. The other, the branch, public school or town library, unpretentious in nature where the books are stored in cases around the room. Here the decorative feature is secondary and utility of light plays a more important part.

It is quite common practice to install decorative fixtures in the high ceiling reading room of buildings of the first class. These supply a moderate intensity of general illumination, necessary for supervision and to prevent severe contrasts of brightness, but are seldom designed to supply enough light for continued reading. All too frequently, the decorative value is apparently

the only element of design given sufficient weight, and examples are well known of glaring and hence ineffective installations. Unshaded lamps are studded in huge clusters, sometimes unfortunately in the field of view. It is quite out of the question to lay down specific rules on this phase of lighting, for individual taste varies, and earnest cooperation between the architect, fixture specialist and illuminating engineer is advisable.

In addition to the general illumination of from 2 to 4 ft.-c., local lighting should be supplied on the tables. These lamps should be very carefully chosen, and so placed that direct or reflected glare is minimized. Many standard types in wide use are most inappropriate and productive of eye fatigue. A number of special designs are available which carry out the principles outlined in the article by Mr. Luckiesh, referred to in the bibliography. An even distribution of light over the table top, of an intensity of from 6 to 8 ft.-c., is suitable, although higher intensities are sometimes necessary where faded manuscripts or books with very fine type are likely to be used.

The lighting in the library at the University of Michigan affords an excellent example of cooperation between the engineer and the architect. Inverted reflectors of mirrored glass, with type C lamps, are placed on the tops of the book-shelves around the sides of the room. The ceiling is relatively high, finished in a light cream. General indirect illumination is provided. Reflectors were chosen and placed with reference to the ceiling, so that all spotted effect is eliminated. Professor Higbie designed a table lamp which is in the form of a continuous trough, finished on the exterior to harmonize with the room decorations. This acts largely by diffuse reflection and the quality of illumination on the table top is of a high order.

As mentioned, in the reading room of the second class of buildings are located the book stacks, and general lighting with the indirect systems is the most logical method of meeting the requirements. With the present day high efficiency lamps, it is advisable to supply from 6 to 8 ft.-c. throughout the room, eliminating the necessity and bother of local or table lamps. The diffuse character of the illumination thus produced gives excellent lighting on the vertical surfaces of the stacks.

The catalog room of the city library is generally lighted by massive ornamental fixtures, and the remarks given under the reading room apply to this part of the building. Simple brackets, attached to the filing cabinets, carrying relatively low wattage lamps in deep bowl or enamel reflectors, increase the intensity of illumination in that region from 6 ft.-c. to 8 ft.-c.

The periodical rooms and special reading rooms are similar in nature to those of the small library, and the type of lighting suggested there fits these conditions.

In the stack room, the titles and numbers on the books must be readily discernible, and an average intensity of from 2 to 4 ft.-c. is desirable. Twenty-five-watt or fifty-watt tungsten lamps with deep bowl opalescent glass reflectors, attached to a line of overhead conduit over the aisles, on 6 to 10 ft. centers, will fulfill the demand. Where the aisles are of considerable length, three-way switches at both ends are economical in enabling the attendant to obtain the required light and to extinguish it after the desired book has been obtained.

In the entrance and corridors, as with the museum, the decorative element is predominant, and any of the systems of lighting can be applied here, provided an intensity of from 1 to 2 ft.-c. for safe ingress and egress is available. Enclosing units offer certain advantages from a standpoint of diffusion and can well be supplemented by wall brackets of ornamental design.

The principles of industrial lighting apply to the bindery, which is a far more important element of library operation than most of us realize. The huge circulation of our large libraries entails a great deal of repair work and rebinding. As with any factory, high level, well diffused light will be productive of increased output.

LIGHTING OF MUNICIPAL, COUNTY AND STATE BUILDINGS

The larger portion of these structures is devoted to private and clerical offices, the illumination of which has been thoroughly covered in the I. E. S. TRANSACTIONS. Entrances, corridors, and reception rooms are similar in demand to those in the museum, and where inscriptions and mural paintings are present, care should be taken to see that the type of unit chosen for lighting permits these to be seen in a clear and effective manner.

Committee and jury rooms have the same general requirements as the office, although a lower intensity (3 to 5 ft.-c.) is sufficient. In many instances, however, these rooms are finished in dark wood, which makes the lighting problem considerably more complex. Bracket units with unshielded lamps must be avoided and diffusing enclosing globes, well out of the angle of view, offer probably the best solution. The character and design of the supporting fixture will depend on the elaborateness of the decoration. The beautifully finished room pictured in Fig. 10, would be much more pleasant if the wall brackets were omitted and the general lighting fixtures placed closer to the ceiling.

Figuratively speaking, light and justice are always associated, and yet an investigation of the lighting in our court and assembly rooms shows them to be, in many instances, dark and dingy. When necessity arises for proving physical facts by visible evidence, it is often difficult to observe the details of the exhibit. During a court trial, it is certainly desirable that the judge and jury should see the witness with the utmost distinctness as testimony is being given, and it is evident that proper lighting is essential.

Many of our court rooms are still illuminated by open burner gas jets, or by old gas fixtures which have been slightly altered to accommodate such electric lamps as would go inside the globe without any forethought from the standpoint of intensity, distribution or diffusion.

The general lighting requirements are similar to those of an auditorium, and lighting units should be suspended well out of the line of vision, even though of a decorative nature. Wall brackets at the front of the room are especially objectionable, as they are continuously in the field of view, and one's attention is naturally directed toward the judge and witness. An example of such an installation is to be seen in Fig. 11.

While stage effects are not in especially good taste, there is no reason why advantage should not be taken of some of the principles utilized so effectively on the stage. If the director desires to focus the attention of the audience on a particular part of the scene or one actor, he illuminates this area to a higher intensity by the use of a spot lamp of some sort. If the con-

Fig. 10.—A committee room handsomely finished in dark woodwork with its beauty reduced by sharp contrasts in brightness due to improperly used wall brackets.

Fig. 11.—This court room would have been much more comfortable if the bracket fixtures at the front and sides had been eliminated and the pendant units raised several feet.

Fig. 12.—A well lighted bank using 300-watt lamps in semi-direct bowls on centers 18 x 32 ft. The fixtures are simple yet dignified and provide a uniform intensity of 5 ft.-c throughout the main banking space.

Fig. 13.—A night view showing a typical cage grill fixture employing 25-watt lamps spaced about 14 in. apart. The continuous housing conforms with the architectural features of the bank and the well diffused light on the counters facilitates the clerical work.

struction of the building is such as to permit a suspension type spot lamp to be concealed from view, it would seem fairly logical to direct the light from this lamp on to the witness stand. A sharply defined spot would not be desirable, but on the other hand, one which shaded off gradually would produce the desired effect without being noticed by the casual observer.

There are many cases which come to trial where the verdict depends on a close examination of the evidence, as in the case of forgery, or an erasure in a document. Much time may be lost if the case has to be adjourned to an adequately lighted room in order to view the exhibit. If convenience outlets are provided to which local lamps giving a high intensity of illumination can be attached, this work can be carried on without loss of time. The accurate type of color identification unit, providing illumination of a high intensity over a small area of a true daylight value, should be useful. In his paper on "The Relation of Light to the Proof of Documents" presented before the Illuminating Engineering Society, Mr. A. S. Osborn pointed out the importance of this question and the desirability of employing some such scheme as suggested.

BANK LIGHTING

The lighting system in the bank should be such as to impress the patrons with the dignity of the institution, and yet eliminate any idea that the building is simply a cold storage place for currency, by making the interior comfortable and inviting. A high intensity of illumination will eliminate eye fatigue and thus prevent opportunities for errors, and will increase the speed of the clerical force. It is an asset in advertising the bank and many deem it advisable to leave the lamps in service at night for this purpose, as well as for the protective value of the light.

With the high efficiency of the present-day illuminants the old form of local or drop lighting is gradually being eliminated, and the multiplicity of unsightly cords and tin shades which formerly occupied the space behind the cages, is becoming a thing of the past. The main banking space should be equipped with general lighting of an intensity of from 4 to 6 ft.-c. Almost any form of fixture which harmonizes with the architectural features might be used, providing it fulfills the general requirements as

to distribution and diffusion. If the general lighting is not sufficient, patrons' desks should be equipped with local units producing an intensity of from 8 to 10 ft.-c. The general type of these units should be similar to those recommended for reading in the library, and they should be so located as to prevent direct and reflected glare. The exterior of the fixture obviously harmonizes with the other metal work.

A pleasing, yet simple and inexpensive installation of semi-indirect units is pictured in Fig. 12. With a system such as this, larger lamps can be installed in the units over the working portions to provide the higher intensity needed here for bookkeeping.

The general lighting system is often supplemented by cage grill fixtures to raise the intensity at the various wickets to a value of approximately 10 ft.-c. This greatly facilitates clerical work and reduces errors. In the installation shown in Fig. 13, 25-watt tungsten lamps on 14-in. centers, are placed in a continuous mirrored trough reflector. The fixture is finished to conform with the room decorations. The distribution of light is such as to prevent glare and a diffusing glass plate over the opening prevents annoying reflections of lamp filaments.

The vaults are used primarily for the storage of valuable documents, and little actual work is carried on here. A lower intensity (3 to 4 ft.-c.) suffices here. In most instances it is inadvisable to pierce the armor plate of the safe to furnish electric current for lighting purposes. A convenient arrangement to overcome this difficulty is to locate one receptacle outside of the vault connected to the power supply, and another inside of the vault feeding the lighting circuit. When the steel door is opened, a flexible cable with a plug at each end connects the two receptacles. A circuit breaker installed on the line is sometimes used for purposes of economy, for occasionally, through oversight, the steel door is accidentally closed on the cable, thus short circuiting the line. In the vault itself, diffusing bulb small wattage lamps, without reflectors, are satisfactory in close ceiling type receptacles.

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DISCUSSION

The papers, by Messrs. Powell and Parker, and Messrs. Curtis and Stair were discussed together. See page 570.

RECENT DEPARTURES FROM USUAL LIGHTING PRACTICE IN PUBLIC SPACES AND OFFICES*

BY AUGUSTUS D. CURTIS AND J. L. STAIR**

The world is full of things that lack distinguishing characteristics—things that keep closely to the established order or practice. Even in our own field of lighting, we are often impressed with the sameness—almost unvarying monotony to be found in many of the applications with which we deal.

It is the unusual that gives us the keenest feeling to having accomplished something in the art of the use of light. In other words, to quote Mr. Luckiesh, "Variety is the Spice of Lighting." Unusual should not be mistaken for freakish. Whimsical applications cannot be considered as adding variety. They are merely distracting and have no effect in the advancing of the art. Many of the new uses or methods mark the birthdays or chapter headings in the life of lighting progress. The revolution in lighting can be dated from the invention of the incandescent lamp. Many changes followed immediately upon the production of the gas-filled tungsten (type C) lamp.

The examples that are offered in this paper have required an intimate study of the particular conditions that exist in each case, indicate methods that will find further use and contain ideas that can often be woven into the architectural structure of buildings.

In the illumination of public buildings, the lighting man should feel his responsibility in the emphasizing of the architectural beauties of the interior, as well as providing adequate illumination. The lighting should, in other words, serve or co-operate with the other arts in bringing about complete harmony in the interior. In the lighting of office spaces, the lighting man should keep constantly in mind the fact that power consumption should not enter into the discussion to such an extent as to crowd out the vital interests of working efficiency and humanitarianism.

*A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

**National X-Ray Reflector Company, Chicago, Ill.

The following are a few of the recent departures from usual lighting practice in public spaces and offices and it is for history to record, as to whether or not, they are milestones in the art of illumination.

THE DIXIE TERMINAL.

Before attempting to describe any particular detail in this very interesting building, it will be well to note something of the history of the project.

As most of us are aware, the City of Cincinnati lies on the bank of the Ohio River with the cities of Covington and Newport directly opposite on the Kentucky side. The surface cars from "over the river" have heretofore passed over the suspension bridge and thence into the various downtown streets, adding to the already conjested conditions. For years this condition has become daily more intolerable, and much thought has been given to methods of relief. It remained, however, for Mr. Harry L. Linch, one of Cincinnati's young attorneys to conceive the idea of a terminal building which would take a great part of this traffic from the streets of the shopping district. The services of Garber and Woodward, Architects, were secured to embellish his idea and together they developed the plan of the Dixie Terminal.

The natural lay of the land on the bank of the river helped greatly in this project, as Third Street to the rear of the building is two stories lower than Fourth Street at the front. The Covington cars which use the suspension bridge come straight in at the bridge level and enter the second floor of the South Building. The Newport cars which cross the river above, come into the first floor level of this building. Leading from the two landing platforms, ramps or incline passages connect with the beautiful arcade and concourse in the North Building. These arcades connect with Fourth Street the principal shopping thoroughfare. The arcade and concourse are lined with stores and clever little shops showing the finest of merchandise. The balance of the North Building is devoted to office space.

As many thousands of people pass through the building daily, a very attractive decorative scheme was desired. The arcade, as will be noted from Fig. 2 is done in the Italian Renaissance period, with medallions in shallow relief featured in the vaulted ceiling. In selecting a system of illumination for the arcade

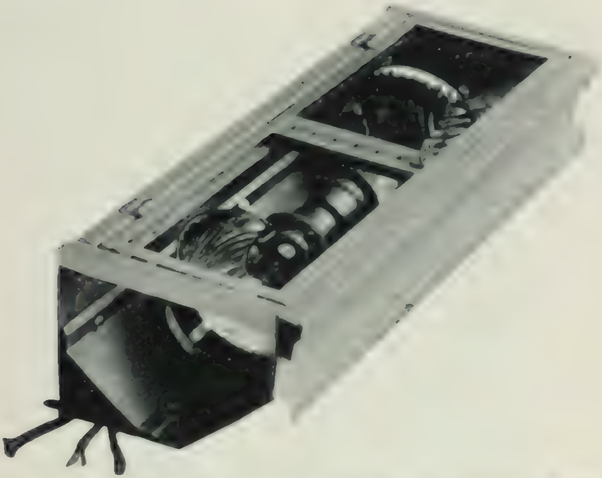

Fig. 1.—Short section of lighting trough used in Dixie Terminal Building Arcade.

Fig. 2.—Night view of the Arcade—Dixie Terminal Building

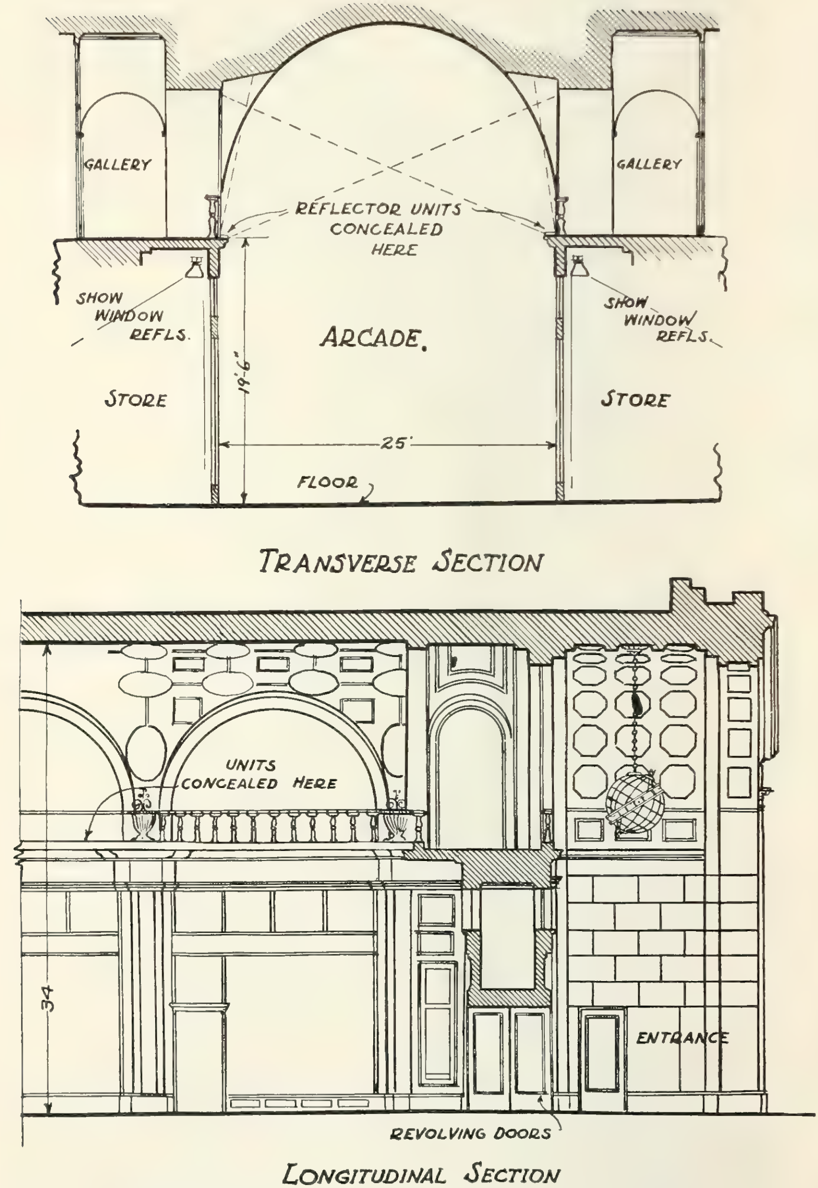

Fig. 3.—Diagrammatic sections of the Arcade—Dixie Terminal Building, showing location of concealed lighting units.

space, it was desired that no light source or lighting accessory should be in view against the decorative pattern of the ornamental ceiling, yet all of the details and coloring should be pleasingly revealed by light thrown upward. At the same time it was necessary to consider the fact that the gallery floor with its rows of shops should be protected from any glaring type of lighting. A system of cove lighting from the cornice at the foot of the baluster rail seemed to be the only practical method of accomplishing this result.

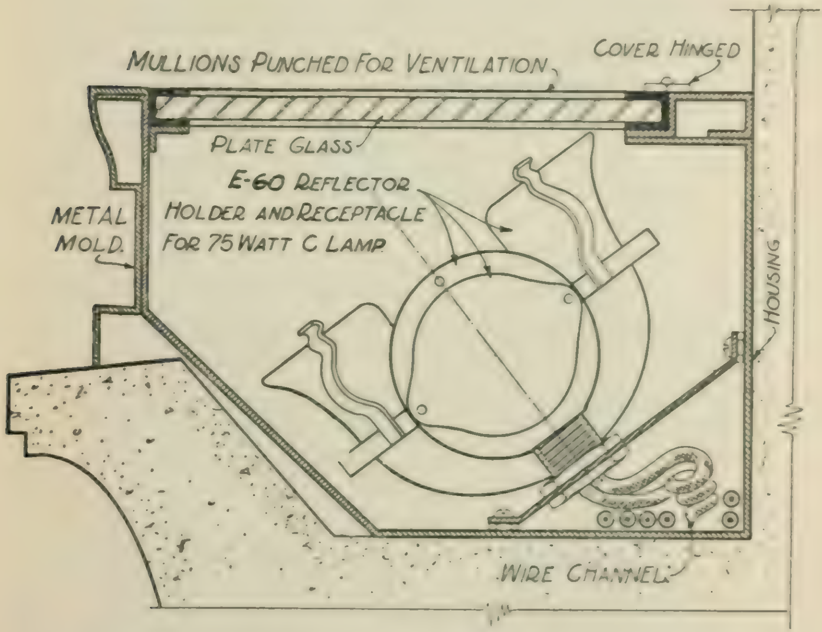

Fig. 4.—Section of housing or lighting trough used in the Arcade cornice—Dixie Terminal Building.

Much care was exercised in the design of the lighting trough containing the reflectors in order to avoid offending the eye of the observer on the gallery level, especially those on the opposite side of the arcade. Figs. 1, 3 and 4 illustrate the arrangement of the reflectors and their relation to the sight lines from the gallery level. A total of 354 mirrored reflectors with 75-watt type C

clear lamps, were used in this work. The various sections are wired to permit of three intensities of illumination. The short sections in front of the columns are on a separate circuit and are used for low-intensity lighting after the rush of the late evening traffic.

The shops are lighted with specially designed semi-direct glass units with cast ornamental hangers. The shop windows are illuminated in a novel manner. All reflectors are recessed above the ceiling level and the bottom opening is covered with a hinged glass door. The glass used is of a low absorption diffusing type, thus concealing all reflectors. Grooves and clips to hold the new color-ray slides with which to secure different color lighting effects, are provided on the bottom doors. A total of 450 reflectors are used in the shop windows.

The Dixie Terminal Building is one of the first office buildings in which totally indirect lighting has been used for all office spaces. This is rather unusual for a building in which office space is to be rented, and the decision to adopt the engineers recommendation as to this type of lighting was reached only after the building committee had made extended inspection tours of the principal office buildings in the United States. As far as we are aware no such extensive tests of all types of equipment and such painstaking investigation of the most suitable form of illumination have been heretofore conducted. The lighting unit which was approved and installed for the entire office space is of the luminous-bowl type. The glassware of the fixture consists of bowls which enclose the indirect reflector equipment. The fixtures have been equipped with oversized diffusers to secure a somewhat greater bowl brightness than is usually obtained with luminous bowl indirect lighting units. About 12 per cent of the light from the lamp is distributed by the diffuser to illuminate the glass bowl which is the decorative cover or envelope of the silvered glass indirect lighting reflector.

Approximately 750 fixtures of 200 and 300-watt sizes were required for the office lighting. A dust cover which fastens into the inner top supporting rim of the fixture serves to support the reflector and diffuser and prevent dust from settling into the outer glass bowl. Each supporting arm of the fixture is so arranged that the process of cleaning is simplified by dropping down only

one side of the bowl. Thus the lamp and reflector can be easily cleaned without removing either. The fixtures are of the same general type as shown in Fig. 13. The reflectors are so designed as to produce an even ceiling illumination, the spacing between outlets and height of ceiling being the determining factors. Figure 5 shows the candle-power distribution curve of the reflector.

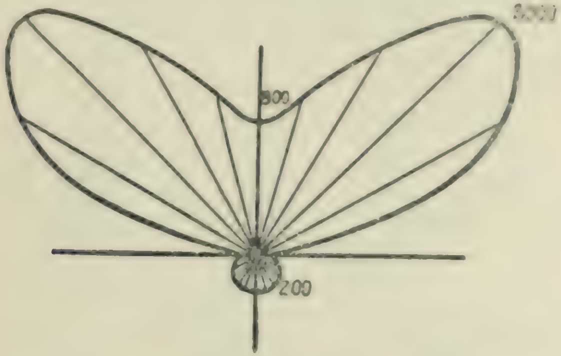

Fig. 5.—Candle-power distribution of reflector used in Dixie Terminal Building.

Recent tests taken in some of the offices show a remarkable uniformity of illumination and intensities at the desk level varying from 8 to 14 ft-c.

GREAT HALL OF THE CUNARD BUILDING.

The Cunard Building is the largest and most important that has been constructed in New York City since the end of the war. The most fascinating feature of this structure is the Great Hall. (See Fig. 8.) Concerning this particular room, the architect of the building has expressed himself as follows: "The eye and mind are at once impressed with a sense of space and dignity unusual in a room designed for the transaction of business. The arrangement consists of two squares terminating the longitudinal axis and separated from each other by a hugh octagon. The North and South sides of the end squares are extended by means of elliptical niches and are roofed by groined arched ceilings, while the octagon ceiling is a dome 65 ft. in height."

The walls, floors and counters are done in Travertine, the rich color of the ceiling being brought down to the level of the eye by Barry Faulkner's maps on the walls of the four niches. Surmounting the Travertine walls is a cornice 36 ft. from the floor and above it soars the intersecting curves and surfaces of the ceiling, a stupendous composition of color, line and harmony by Ezra Winter. Portrayed here is the age-old romance of the sea, or lure of travel. Painted in the circular insets or modeled medallions, sea creatures of many kinds—tritons, mermaids and sirens—express the fascination which the sea has always pos-

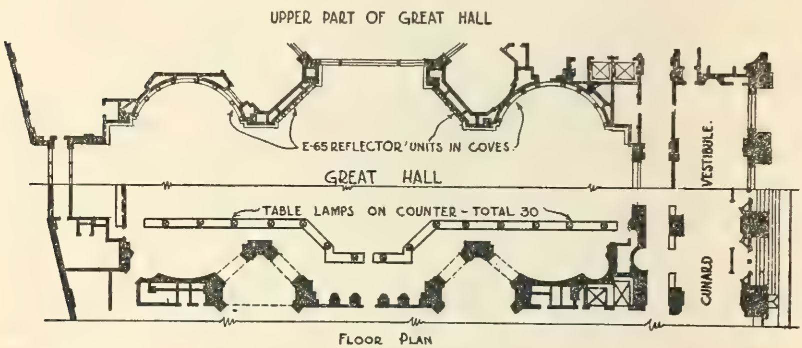

Fig. 6.—Plan of Great Hall of Cunard Building showing location of indirect table lamps and cove lighting units.

sessed for the imagination of the world. The great pendentives of the dome are decorated with magnificent composition depicting the strange craft of the early mariners, Leif Ericson, Sebastian Cabot, Christopher Columbus and Sir Francis Drake. The Great Hall ceiling is one of the few in the country in which strong brilliant colors have been used. The decorations have been produced in permanent flat tones, brilliant or subdued as desired, and without gloss or disturbing reflections.

Picture, for instance, how ineffective the mural decorations and ceiling coloring in the Cunard Great Hall would be without a proper lighting method by which the artistic features could be viewed with satisfaction. Those who view this lighting installation, especially those who have travelled abroad where ceiling

architecture and decoration is so prevelant, will appreciate the handicaps under which the architect and artist of years gone by labored in having the evidence of their genius properly displayed.

A very important feature of the Great Hall, is the counter over which the business is transacted. It runs down the hall on

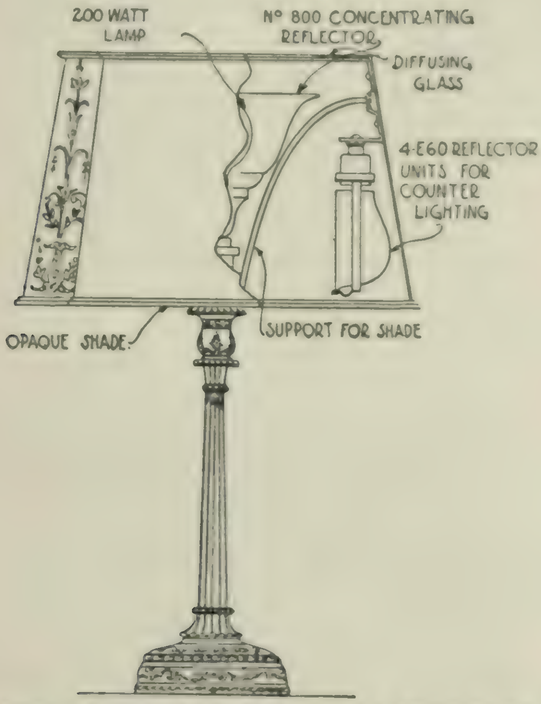

Fig. 7.—A drawing of the special table lamp used to illuminate the Great Hall of Cunard Building.

each side in straight lines, unbroken except beneath the central dome. Upon the dark cork top of the counter are mounted special lamps that supply the principal general illumination for the Great Hall. The thirty counter portable lamps each contain a silvered reflector of the concentrating type supported by special holder and for use with 200-watt type C lamp (See Fig. 7). This reflector unit supplies the upward component of the illumination. Each lamp also contains four silvered reflectors designed for 40-watt lamps and tilted at an angle for the lighting of the counter area upon which maps and deck diagrams are spread out between

the standards. The shade of the portable lamp is opaque. A diffusing glass top is mounted over the indirect lighting reflector unit.

Supplementing the upward illumination delivered by the counter lamps are sixty cove lighting units each with 100-watt type C lamp and installed in the cornice at the base of the ceiling dome. The total power consumption for the general illumination is 12,000 watts. The dimensions of the Great Hall are 78 ft. wide, 183 ft. long, ceiling height 65 ft., floor area 14,274 sq. ft., watts per square foot 0.84. This may seem an extremely low power consumption especially to advocates of high intensities, but results show that for interiors of this character it is sufficient.

FIELD MUSEUM.

The Field Museum of Natural History in Chicago was established in 1893, at the close of the World's Columbian Exposition. The founding of a scientific institution of this character was made possible by a gift of one million dollars by Mr. Marshall Field, whose name the institution bears and who at the time of his death bequeathed a further sum of eight million dollars of which half was designated to be used for the erection of a building, and the remainder as an endowment fund. The institution has been recently removed from its temporary home in Jackson Park where it has been occupying the old Fine Arts Building of the World's Columbian Exposition, to Grant Park at the foot of Roosevelt Road on the Lake front of the downtown business section.

The building now occupied is 350 ft. wide and 700 ft. long. Two of the four floors are devoted to exhibition purposes, while the ground and third floors are used as working spaces for the scientific and maintenance staff. The main central area of the building known as Stanley Field Hall, rises to the entire height of the building. The remainder of the structure is divided into floors. The exterior of Georgia white marble is 80 ft. in height and treated in monumental Greek architecture of the Ionic order. The principal facades are divided into a large central pavilion with two long wings terminated by a smaller pavilion at each end. The architects of this structure, Graham, Anderson, Probst and White, have given to the City of Chicago and the country a

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Fig. 8.—View of Great Hall Cunard Building, New York City, showing effect of illumination by special indirect lighting counter lamps.

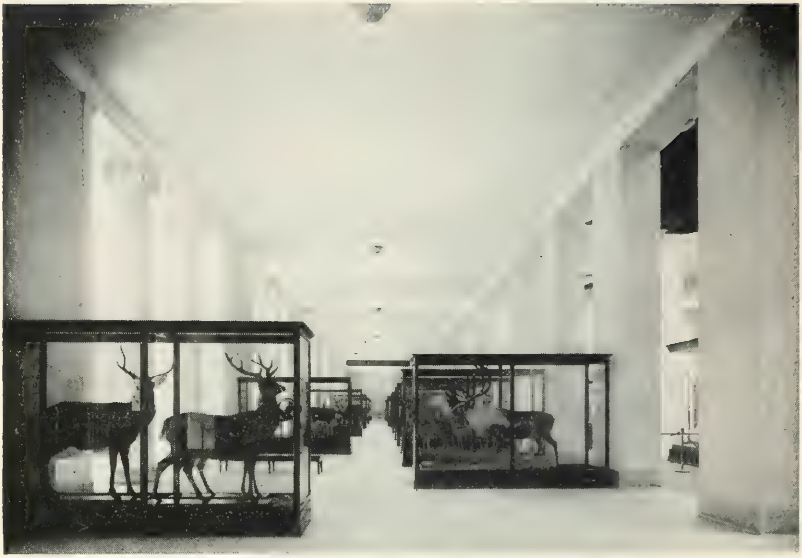


Fig. 9.—View of George M. Pullman Hall, Field Museum.

Fig. 10.—The President's office, Detroit Edison Co.

masterpiece of monumental building having distinction and dignity commensurate with its purpose and origin.

There are many museums containing exhibits of the world's rarest treasures secured after many years of travel and research which formerly failed to receive the interest and support of the public, partially because of the inadequacy of the lighting provided in the exhibition halls. Because of the nature and distribution of displays the lighting requirements in a building such as the Field Museum are very different from those in an art gallery where the light is usually concentrated upon the wall areas. The adoption of totally indirect lighting is somewhat of a departure from the usual method of lighting a building of this character, and proves to be particularly desirable for several reasons.

(a) Reflections from the large number of glass surfaces that ordinarily reflect bright light points to the observers eye, are minimized.

(b) The displays are viewed from all angles, hence a sky-light effect is desired when artificial illumination is required.

(c) The quality and restfulness of the illumination provides eye comfort for the public in constant concentrated observation. A protracted review of exhibits in a museum of this nature is physically tiring and the removal of eye strain is desirable.

(d) The diffusing lighting system assists in fullfiling the desire of the architect to obtain a visual effect of spaciousness in the interior.

The architects and Board of Directors of this museum of which Mr. Stanley Field is president, having in mind the above essential points, before coming to a decision, installed for practical working tests, in one hall of the new museum itself, examples of all four types of lighting units as recognized by the Illuminating Engineering Society, that is direct lighting, semi-indirect, luminous-bowl and indirect lighting fixtures.

The type of fixtures adopted for the principal exhibit halls, as seen in Fig 9, is a simple shallow metal bowl totally indirect unit equipped with silvered reflector designed for 500-watt lamp hanging in a pendant tip-down position. The fixture bowl is suspended on the average of 60 in. from the ceiling. The lighting fixture is finished in a washable cream which blends into the

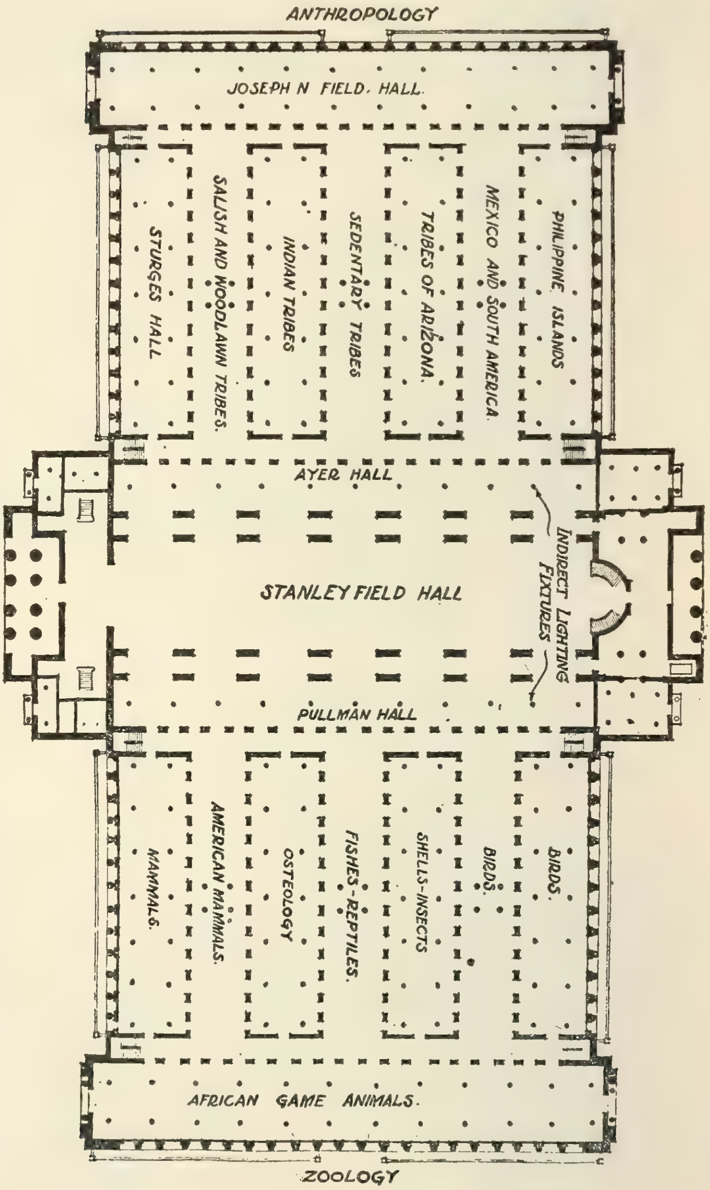


Fig. 11.—Plan of first floor of Field Museum, indicating location of indirect lighting fixtures.

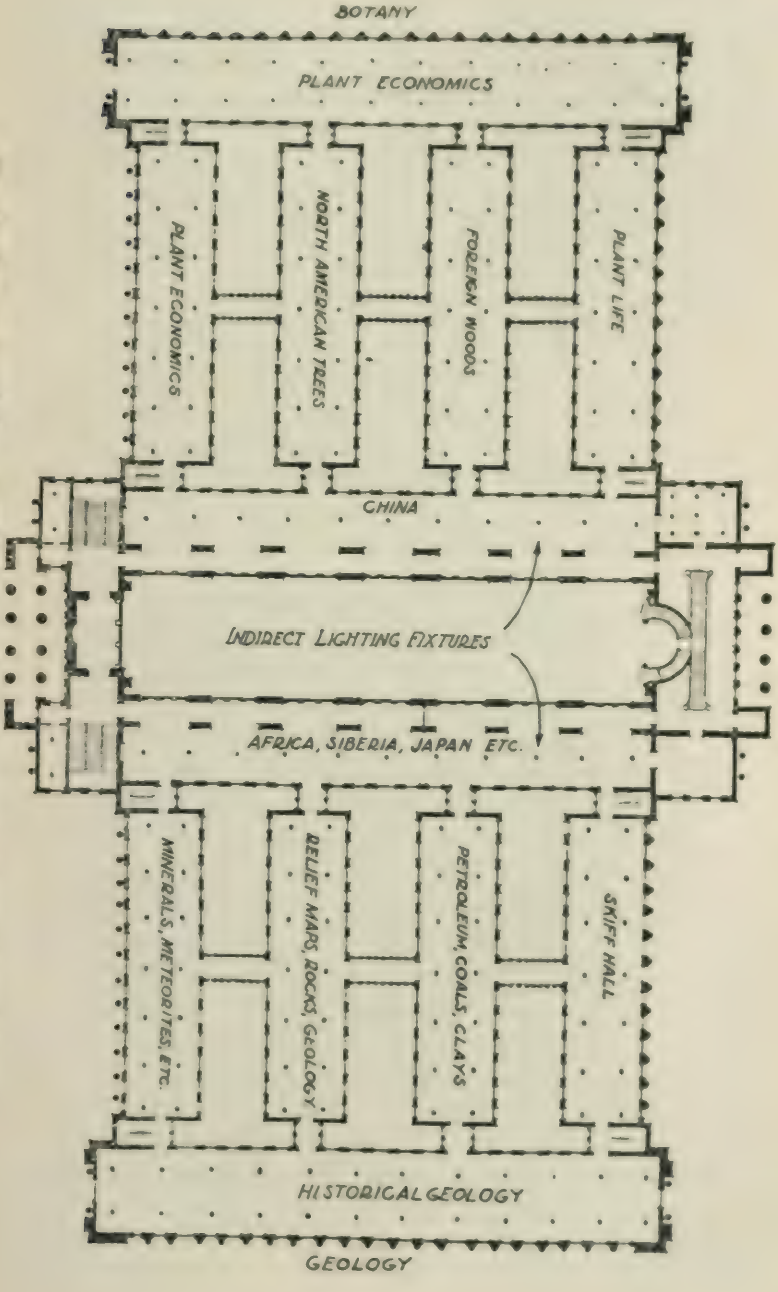


Fig. 12.—Plan of second floor of Field Museum, indicating location of indirect lighting fixtures.

ceiling coloring. The plan of the first floor as shown in Fig. 11, and the second floor (Fig. 12) will give an index of the arrangement of exhibition halls and also show the location of the indirect lighting units as installed in the building. In a typical area such as to be found in Sturges Hall on the first floor, each lighting unit takes care of an area of 21 by 28 ft. In a typical area such as found in Pullman Hall, each lighting unit provides illumination for an area of 28 by 30 ft. Since this hall and Ayer Hall are adjacent to the Stanley Field Hall, they also receive illumination from the units installed in the latter space. The ceiling height of the first floor is 21 ft. 6 in. and the second floor, 18 ft. 6 in.

DETROIT EDISON COMPANY.

The general public looks to the central station company in any community to set the standard of illumination practice. The methods, therefore, that are employed by the central station in the lighting of its own buildings have an important effect on the use of artificial lighting by its customers. The officials of the Detroit Edison Company had this point in mind in selecting the system that is now in use in their new office building. There were other points, however, that were given careful consideration in selecting equipment. It was desired that the method finally adopted should be characterized by an absence of glare that might cause eye strain,—that a uniform illumination should result in all parts of the office space,—that the fixtures when installed should present a cheerful and pleasing effect and that the lighting equipment should be of a type that could be easily maintained.

It will be noted in the description that follows that the intensity of illumination employed throughout the entire building is of a higher value than is ordinarily to be found in an installation of this character. In this respect, the Detroit Edison Company is carrying out one of the tendencies in the development of the lighting art. The trend is toward the use of higher intensities in the use of artificial illumination. Where 2.0 or 3.0 ft-c. was considered sufficient a few years ago for office lighting, we now think of 6.0 or 8.0 and in some cases 10.0 ft-c. as being the desirable intensity. Higher intensities in lighting have been found to improve greatly the production in the industries, to aid the merchant in making quicker sales of merchandise and to stimulate the efforts of office employees.

One of the next steps in illumination practice is, therefore, the building up of intensities for practically every requirement. When we consider that with daylight we receive from 50 to 100 ft-c. it becomes apparent that artificial lighting intensities are still comparatively low. It is not in the least fanciful, then, to expect artificial lighting in a few years to be on what we now consider a very high plane of intensity. In the use of high intensities, it will of course, be necessary to diffuse the light and protect the eye from the harmful glare of the light source.

Before making the final selection of the lighting system that was eventually adopted the Detroit Edison Company made representative installations of direct, semi direct and indirect lighting. The units were installed in typical areas where the room dimensions, decorations and furnishings were similar to those in the new building that was then under construction. With the various types of units thus installed, an opportunity was afforded to study:—

(a) The cost of operation, (b) the cost of maintenance, (c) depreciation, (d) intensity of light delivered, (e) glare effects and the seeing efficiency for each type.

For the various types of lighting units tested, there was not a great difference in the average intensity of light delivered. A value of 10.0 ft-c. had been previously determined upon as the minimum average intensity desired. It was found that this average intensity was exceeded by several of the units, especially when 200-watt lamps were used in each outlet. Some of the better styles of direct lighting units gave about 15 per cent higher average readings than the semi-indirect and totally indirect luminous-bowl units, while some of the dense direct lighting units gave a lower average intensity than the indirect. As a result of the test thus made, 200-watt lamps were selected for the general office illumination, and 300-watt lamps for each outlet in the drafting room.

It was found that uniformity of diffusion of light was a far greater variable than the average intensity obtained from the various types of units. This factor ranged from 20 per cent variation for the totally indirect system to 100 per cent for some of the direct lighting types. It was considered important in this

installation that the maximum uniformity of illumination be obtained inasmuch as the outlets were located irrespective of the location of partitions and office furniture.

In getting at the cost of maintenance, a careful check was made of the time required to clean the various types of lighting units. One of the operations consisted in noting the number of parts that were necessary to remove in order properly to clean the glassware of the fixture and replace the lamps. Note was also made of the liability of breakage in the cleaning and relamping of the fixture. The three principal factors which cause depreciation and result in a loss of illumination intensity will bear repeating—dust collection on the lamp and accessories, the soiling of the ceilings and walls, and the ageing of the lamps.

The relationship between time for cleaning periods in weeks and the percentage of original efficiency of the lighting system, has often been shown. Tests indicate that a decrease in lighting efficiency of approximately 10 per cent a month results from accumulation of dust and dirt on the lighting equipment. If lamps and fixtures are cleaned regularly, every two months, one may expect an average of illumination throughout the year to be at least 80 per cent of that received when all of the equipment is clean.

To insure proper maintenance the Detroit Edison Company employs a competent man under the direction of the chief janitor to carry on the work of cleaning and relamping of fixtures. This man devotes his entire time to maintenance, and since there are about 2,500 fixtures in the installation, each lighting unit is thoroughly cleaned every four weeks.

The totally indirect system was adopted by the building committee, using fixtures of the types shown in Fig. 13. For the corridors, toilets, etc., direct lighting units were selected. In the main entrance lobby, three ornamental iron ceiling fixtures were installed. These fixtures were equipped with bare lamps tinted to a warm yellow color.

One of the styles of lighting fixture consists of a solid metal opaque unit of shallow design containing silvered reflector equipment, with lamps operating in a horizontal position. The application of this fixture can be seen in the illustration of the President's

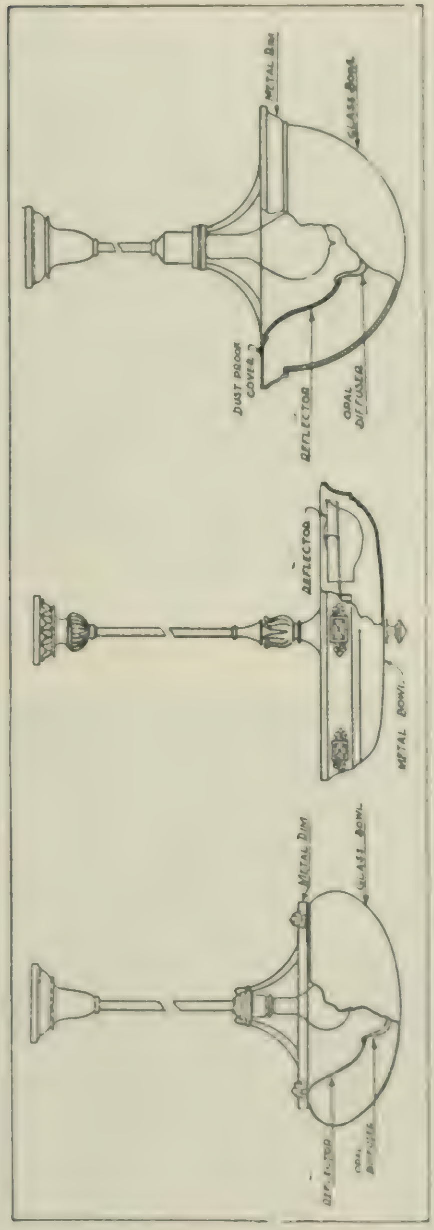


Fig. 13.—Types of indirect lighting fixtures used in Detroit Edison Co. Building.

office, Fig. 10. What is known as the "luminous bowl" indirect lighting fixture is used throughout the office and drafting room space. The illustrations of the general office space, Fig. 14, give a clear idea of the appearance of the indirect fixture with a plain glass bowl. This bowl also contains a silvered reflector designed for indirect lighting and having a diffusing cup which illuminates the enclosing bowl to the proper brightness. It will be noted that the diameter of the reflector is the same as that of the bowl opening. Because of the fact that two pieces of glass fit together at this point accumulation of dust inside the fixture bowl is prevented to a large extent.

Another style of fixture of the luminous bowl type is used in the drafting room, Fig. 15 and in the private offices, Fig. 16. This fixture has a special feature which simplifies its maintenance. See Fig. 13. A dust ring or cover fills up the space intervening between the reflector and the outer edge of the bowl and prevents dirt from settling into the glass container of the reflector equipment, and at the same time affords a means of support for the silvered reflector. A fixture of this type is cleaned with little effort, since there are no parts to be removed in the usual maintenance operation.

A point of interest, and one which has an important bearing on the lighting results, is the care with which the finishes were selected for the ceilings and walls. Several of the most suitable paints for this purpose were applied to wall surfaces and subjected to severe tests—such as fire and washing compounds. The paints tested varied greatly as to their permanency. The one finally adopted is known as BB standard semi-gloss wall paint with carbon gray and ocre. A test of the reflection co-efficient of this paint indicated a value of 48 per cent. In some of the private offices, ceilings are painted with zinc and oil stipled and of a light cream color. Other ceilings are unpainted, and have been given a smooth flat white putty coat plaster finish.

Foot-candle readings taken three months after the installation was put into service show the average lighting intensities to be as follows: Typical office space, 10.2 ft-c.; drafting room 18.7 ft-c.; corridors 0.9 ft-c.; and president's office 11.3 ft-c. The uniformity of the illumination is shown in accompanying chart,

Fig. 14.—Illumination of typical general office space, Detroit Edison Company.

Fig. 15.—Portion of one of the drafting rooms, Detroit Edison Company.

Fig. 16.—Typical private office, Detroit Edison Company.

Fig. 17.—Main banking room—Cosmopolitan State Bank—Chicago, Ill., showing effect of illumination delivered from indirect lighting units in the top of bank screen.

Fig. 18. Conditions under which the illumination tests were made to show the uniformity are as follows: Outlet spacings are 9 ft. 4 in. by 8 ft. 9 in.; ceiling heights are 10 ft. 10 in.; suspension distance from top of reflector to ceiling 2 ft. 6 in. One 200-watt lamp is used per fixture in the office space and one 300-watt lamp per outlet in the drafting rooms.

COSMOPOLITAN STATE BANK.

The unusual features in connection with the lighting of this

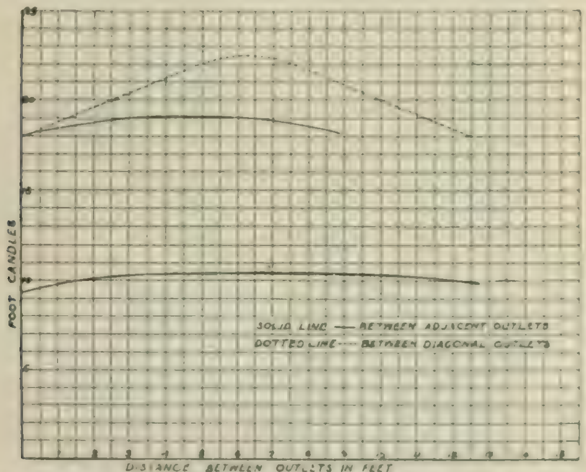
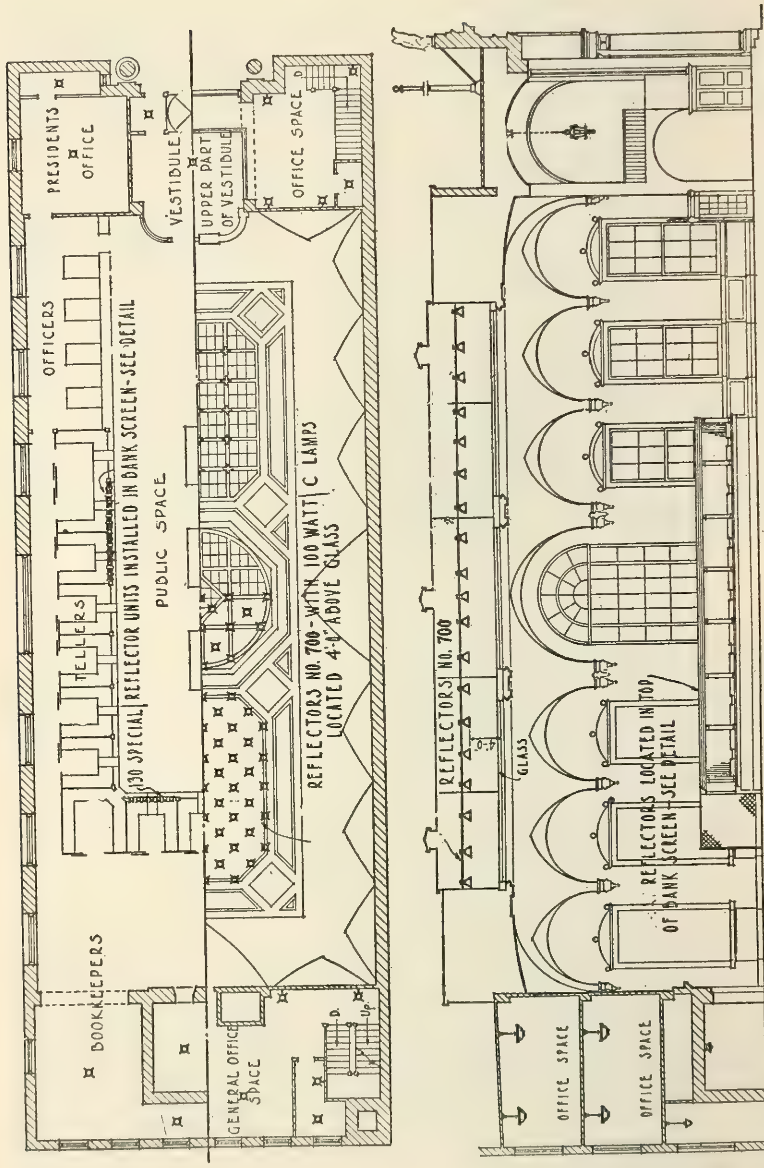


Fig. 18.—Chart showing the uniformity of illumination delivered by indirect lighting fixtures in Detroit Edison Co. Building.

bank interior is the practical elimination of hanging fixtures. (See Fig. 17.) By combining the artificial skylight scheme with that of placing indirect lighting reflector units in the top of the bank screen, a very harmonious lighting result has been accomplished.

Effective lighting is one of the greatest factors in emphasizing the bank's individuality. In a case of this kind, the lighting scheme not only provides illumination of the proper quality for the public space of the bank, correct intensity for the working area, but also brings out the architectural beauties of the interior.

It will be noted from the diagram in Fig. 21 that the reflector units are placed in a continuous row in the top of the bank partition, thus entirely concealing from view all the lamps and accessories. The total area of the banking room is 4,876 sq. ft.;



Figs. 19 and 20.—Half-floor, half-ceiling and section of Main Banking Room, Cosmopolitan State Bank.

ceiling height 33 ft. The lighting equipment in the top of the bank cage partitions consists of 130 silvered reflectors with 75-watt lamps spaced 12 in. apart. Over the ceiling window 135 silvered reflectors with 100-watt lamps are suspended 4 ft. above the glass. All units are wired on two circuits for flexibility. The office spaces of the bank are lighted with totally indirect fixtures. (See Figs. 19 and 20.)

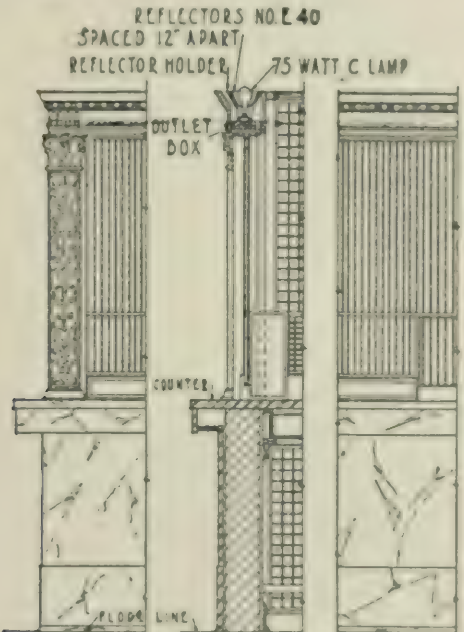


Fig. 21.—Section of the bank screen containing indirect lighting reflectors.

The rapid advance in the applied art of illumination retarded by the World's War, is again under way. It is obvious that in a short paper of this nature, it is impossible to mention the recent unusual departures in lighting of such interiors as churches, theatres, hotels, governmental buildings, lodge halls, etc. that will have an important influence on the future practice.

It is, of course, only by proper co-ordination of the effects of those engaged in the art, science and practice of illumination, that most rapid and permanent advancement is possible and that the greatest good will result in providing the so called civilized users of artificial light a greater eye comfort and better living conditions.

DISCUSSION

The papers, by Messrs. Powell and Parker, and Messrs. Curtis and Stair were discussed together.

S. G. Hibben: It occurs to me that of all the public servants, Caucasian or Ethiopian, those most conspicious by their absence are the Gold Dust Twins. In no place is cleaning more necessary than in the public buildings, and this applies equally to our homes and residences, so I hope the ladies present will take this to heart.

Lighting fixtures, particularly of the inverted bowl types, are neglected either through a fear (growing out of ignorance) of touching things electrical or from pure negligence, until the lighting is condemned and people coming into the home or the store comment upon the unsightly or gloomy appearance. Cleaning is certainly important.

Cleaning glassware is a simple matter, but it has not received enough publicity. We have methods of cleaning glassware which everybody ought to study. In general we can remove the dirt with ordinary soap and water. Sometimes, in case of metal reflectors and units exposed to sulphurous acids, cleaning requires some acids, and we know that ordinary crystal glassware can be better cleaned by dilute acid, such as a one or two per cent solution of nitric acid. I would like the ladies' attention called to the fact that ordinary soap solution, when cleaning lighting fixtures, ought to be removed. One of our greatest faults in cleaning equipment is merely to wash with soap, and leave an almost infinitesimally thin soap solution on the fixture to which film the next cloud of dust adheres. We ought to wipe lighting fixtures, either metal or glass, with paper towels, tissue paper, etc., and not with a greasy rag.

We can clean paints also and in cleaning paints, the question of the light color of interior finishes has a tremendous importance. I want to call attention to something in this connection, namely that when we can increase the reflecting value of any surface by a small percentage, the effect upon illumination is tremendous.

Suppose we have a room in which a lighting fixture will produce a certain amount of illumination on the working surface.

We find that the illumination will be increased by an amount which can be expressed by the formula $\frac{1}{1-K}$, where K is the coefficient of light reflection.

Now, suppose in our home we have a surface of color of medium yellow. It may reflect fifty per cent of the light that strikes it. Then the cumulative effect of the surroundings, if K equals fifty per cent, will be one over one minus five-tenths, or a factor of two. In other words, the useful illumination may be twice that which may be received from only the fixture itself.

We may wash this surface and increase the light-reflecting value of that same surface to a factor of eighty per cent, which is not unusual. Then, one over one minus eight-tenths becomes five. In other words, when we had double the illumination with the dirty interior, we will have five times the illumination with the clean interior. The cleaning of *all* surfaces is important.

Put a mirror on a pole to look into the top of an indirect or opaque unit, wool gloves provided for the janitor to use, holes in the bottom of the globes in which the maintenance man places a finger,—all those little items of cleaning we ought to consider in getting our efficiency up to the utmost point. I have said before, and I wish to reiterate now,—in maintaining lighting installations of all kinds, water is cheaper than watts.

E. L. ELLIOTT: While I have not yet had an opportunity of personally inspecting the general offices of the Cunard Building, I can see from the views that Mr. Curtis has shown that the illumination is a magnificent example of what can be obtained by the application of illuminating engineering principles when excellence of lighting results, and not the necessity of hanging up a mass of art metal, is the object sought. I can conceive of no more perfect specimen of interior lighting than that shown by Mr. Curtis to-day.

Mr. Goodwin pleads for a greater use of illuminating engineering principles by the fixture makers and dealers. Mr. Curtis has shown us how the finest results can be obtained without the use of any "fixtures," in the commercial sense of the term, at all. Here is a flat contradiction of interests; how is it to be reconciled? I have watched the efforts of Mr. Curtis from the beginning, and I know that he has met with the most strenuous opposition from the fixture interests, and not infrequently from the exponents of

illuminating engineering. The simple, cold fact is, that "business is business," and the fixture makers profits depend upon how much, and how expensive art metal and glassware he can install, and not upon the excellence of results in illumination which they produce. From the illuminating engineering view point the best results are obtainable without the use of any visible fixtures whatever.

W. L. GOODWIN: The National X-Ray Reflector Company has adopted a sales policy which induces jobbers, dealers and contractors to aggressively promote the sale of their product. In other words, there is a profit on product for the Company which contributes to sales promotion or merchandise distribution. In other words the Company is not compelled to meet sales resistance as a result of improper sales policies.

C. M. MASSON: I wish to ask Mr. Curtis a question. In the installation in the Cunard Building you said that there is an average consumption of eight-tenths watts per square foot, and that everybody on the job agreed that is sufficient. Now I want to ask if, after allowing for deterioration and dust accumulation, do they think the illumination will still be satisfactory?

A. D. CURTIS: I think it will stand a slight decrease in illumination and still be perfectly satisfactory, but with a maintenance of lamps and cleaning of fixtures it is believed to be sufficient by the engineer.

E. A. ANDERSON: As Mr. Powell has indicated, there is certainly an important opportunity for better practice in court rooms both with regard to the artificial lighting and natural lighting as well. In so many cases the court room is arranged so that the jury must face the windows and in consequence, while the faces of jury men are very well lighted, the features of the attorney who is talking to the jury are left in darkness. This is also very likely to be the case with the witness on the stand. A reverse arrangement would not only enable the jurors to judge the facial expressions of the attorney and particularly the witness, but furthermore, the eye strain which now comes from the constant presence of the windows in the field of view would be relieved and a higher degree of interest and attention on the part of the jurors might be anticipated.

If for architectural reasons a change of the arrangement of the room is not practical it would be better if the lower sections of the window at least, were fully shaded to a height of eight or ten feet above the floor or in some cases it might really be better to omit the daylight entirely and depend upon a properly arranged artificial lighting system designed to provide efficient lighting.

COMMENTS ON HETEROCHROMATIC PHOTOMETRY AND THE THEORY AND OPERATION OF THE FLICKER PHOTOMETER

BY A. H. TAYLOR**

Heterochromatic photometry and the theory and application of the flicker photometer have been extensively discussed in the scientific literature, several important papers having been presented before this Society. It is not the purpose of this paper to make a complete survey or review of the literature on the subject, but only such parts of it as bear more directly upon a particular development of the theory of the flicker photometer. This development, which apparently has not previously been published, is supported by published experimental evidence which will be cited. The paper also suggests some lines along which further research in heterochromatic photometry should proceed, and gives practical suggestions regarding the operation of flicker photometers.

In photometry two factors are encountered, namely, color and intensity. In most precision measurements an effort is made to eliminate the color difference of the lights compared, so as to confine the measurements to comparisons of the relative intensities of two lights of the same color. Many occasions arise where the color difference must be met, however, and the difficulties of accurate measurement increase very rapidly as the color difference increases. Some eminent scientists have said that there is no such thing as an equality of brightness of lights of different colors. Trotter[1] expresses the matter thus: "No assignable quantity of oranges can be said to be equal to or identical with a score of herrings, and a quantity of red light cannot be adjusted to produce on a white screen an illumination identical with that produced by a green light."

*A paper presented at the annual convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

**Laboratory of Applied Science, Nela Research Laboratories, Nela Park, Cleveland, O.

[1]Illumination, Its Distribution and Measurement, A. P. Trotter, p. 163.

These statements are undoubtedly true, nevertheless various articles of food can be compared on the basis of one common characteristic, *viz.*, heat value, and in like manner differently colored lights can be compared on the basis of brightness, even though this comparison may be very difficult. Needless to say, photometricians are not absolved from the necessity of making brightness comparisons of differently colored lights because of the difficulty encountered or the non-existence of an equality of brightness, but are daily called upon to make such measurements.

It is possible so to adjust red and green lights, for example, that when compared with a photometer the stimulus due to the red is undoubtedly greater than that due to the green, or vice versa. Evidently there is some point between the extremes where the two lights stimulate the retina to an equal amount, though the color difference is still present. Hence at some position between two such lights there must be a point of equality of brightness, where we define the brightness of the photometer screen as the product of the density of reflected light flux and a stimulus coefficient, the latter depending on several factors such as size of field, characteristics of the eye used, spectral distribution of the light, intensity of illumination, etc. In other words, colored surfaces have at least a brightness-factor in common. Additional evidence of this is seen in the fact that red, green and blue lights can be added in such proportions that they will produce the same color and brightness sensation as white light, which is different from each individually. Unless the existence of a brightness-factor with colored lights is conceded, it is useless to proceed, since this is a fundamental assumption in consideration of this subject.

At this point it may be pertinent to consider just what quality of the light we want to measure, and some of the conditions of measurement. It is evident that what we want to measure is the degree of usefulness of the light in making things visible. Since the uses of light are so varied, and the usefulness depends so much on the size, color, etc., of the objects illuminated, it is necessary to be somewhat arbitrary in choosing our conditions and to confine our measurements to the quantity of light necessary to produce a definite brightness under definite conditions of angle of incidence, size of field, etc. The importance of this will be emphasized later.

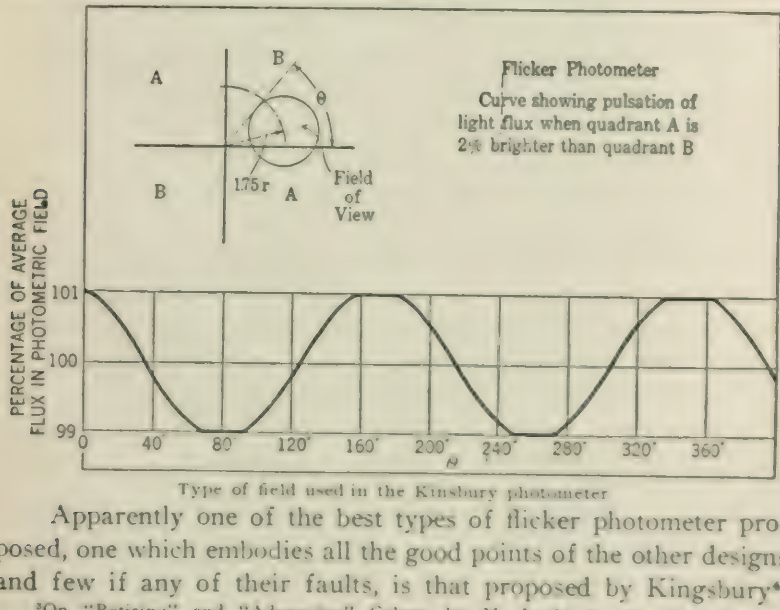
TYPES OF PHOTOMETERS AND METHODS OF BALANCING

Two general classes of photometers are used in heterochromatic photometry, namely, "direct comparison"[2] and flicker. The "direct comparison" photometers consist of those instruments in which the two lights to be compared are viewed side by side in one field. This field may have any one of a number of forms, as follows: a circle bisected into two fields; a central spot and surrounding annular ring; the Lummer-Brodhun type, in which each half of a vertically bisected circle contains a contrast trapezoid, etc. When there is a color match between the lights being measured, these fields are easily balanced, since all except the Lummer-Brodhun contrast field are uniform in color and brightness when balanced, and dividing lines between different parts of the field disappear. (In the contrast photometer the trapezoids are usually about eight per cent darker than the surrounding field when the photometer is balanced.) When, however, there is an appreciable color difference, it is impossible to balance any one of this class of photometers and be certain that it is balanced when everything is stationary, since the field is no longer uniform in color, and the parts illuminated by the two lights are distinctly different in appearance. The difficulty lies in the fact that it is impossible to subordinate color and consider the brightness-factor alone. It is my experience, and that of many with whom I have discussed the matter, that in this case the balance is made by rapidly varying the intensity on each side of the balance point, by shifting either the photometer head or one of the lamps, and then trying to make the balance intermediate between the two points where it is just evident that the photometer is unbalanced. In rapidly varying the illumination in this manner the observer sees that some definite change takes place at some point of the oscillation, though it is impossible to determine exactly where it occurs if the color difference is large. An experienced observer can usually make a balance fairly quickly, though the photometer still looks unbal-

[2]The term "direct comparison" has been quite generally used to describe a certain class of photometers in which the two lights are viewed simultaneously in juxtaposed fields, as differentiated from flicker photometers. It is difficult to see, however, why one method is any more direct than the other, as might be inferred from this designation. It is recommended that the I. E. S. Committee on Nomenclature and Standards consider the proper term to be used to designate this class of photometers.

anced when brought to rest, and it can be moved over a considerable range before the observer is certain as to which light is brighter. The difficulty of the operation increases more rapidly than the color difference since simultaneous contrast seems to intensify the color difference. If this difference is very large another factor becomes apparent, in that the two colored fields appear to be in different planes[3], and there appear one or two "ghost" dividing lines.

The second class of photometers consists of flicker instruments, of which many forms have been devised or improvised. By some means or other they usually present the two lights alternately in a limited area in one field. The transition from one light to the other may be sudden or gradual, depending on the type of instrument used, though in most cases one field comes into view as the other passes out, and a single color is in the field alone for only a very small part of the time. The principal exception to this type of flicker photometer is the Bechstein, which has a concentric circular field. In this each light is viewed alternately in the central spot and the annular ring.



Type of field used in the Kinsbury photometer

Apparently one of the best types of flicker photometer proposed, one which embodies all the good points of the other designs and few if any of their faults, is that proposed by Kingsbury[4].

[3]On "Retiring" and "Advancing" Colors, by M. Luckiesh, *American Journal of Psychology*, April, 1918, p. 182.

[4]*Journal of the Franklin Institute*, 180, p. 215, August, 1915.

The field of this instrument as finally adopted is illustrated in the upper left-hand corner of the accompanying illustration. The photometer cube is divided into quadrants, *A* being illuminated by one lamp and *B* by the other. The field of view is a 2° circle which rotates about the central point of the cube as shown. For calculation of the curve shown it has been assumed that the center of the 2° circle was displaced 1.75 times the radius from the center of the photometer cube. This field is surrounded by a white disk at the end of a white lined tube illuminated by a small lamp. In effect then the observer sees a stationary 2° circle of variable brightness in the center of a much larger illuminated field consisting mainly of the white lining of the telescope tube. The dividing line between the two colored fields passes from top to bottom, left to right, bottom to top and right to left during one complete revolution of the optical system. This appears to be a decided advantage over a field in which the dividing line always travels in the same direction. In operation the dividing lines of the cube are placed out of focus, which softens the transition from one field to the other. When the optical parts of a flicker photometer such as this are set in motion so that the fields are alternated faster than, about 20 cycles per second, it is possible to adjust the intensities of the two lights so that no flicker is aparant. If the intensity of one light is altered by moving the lamp or photometer, a flicker will be apparent at this or a lower speed, but the color will appear constant even though the lights being photometered are of different colors. If the speed is still further reduced, a point is finally reached where the colors of the two lights are apparent, but at this speed it will be impossible to adjust the intensities so that the flicker will disappear, since this flicker is due to alternately viewing two differently colored lights at such a speed that both colors are distinct. In fact, it is found experimentally that the minimum speed at which the flicker can be made to disappear is always appreciably higher than the speed at which the field appears to be constant in color. In operation the speed should be so adjusted that the flicker disappears over a very narrow range of brightness difference, or even so that it does not entirely disappear. A photometric balance is then made by adjusting the photometer or lamps so that the flicker is a minimum or disappears entirely.

THEORY OF THE FLICKER PHOTOMETER AND EXPERIMENTAL EVIDENCE IN SUPPORT OF IT

Earlier in this paper was emphasized the necessity for the assumption that a condition of equal illumination by two differently colored lights could exist, regardless of our ability to determine when it existed. Consider again the type* of photometer field shown in the illustration, where the center of the observation field is displaced from the center of the photometer cube 1.75 times the radius of the observation field. If field *A* is two per cent brighter than field *B*, there will be a pulsation of light flux in the observation field as shown in the curve, and this should cause a flicker under proper conditions.** Whether a pulsation of this nature can be detected will depend on several factors, the most important being the speed of alternation and the magnitude of the pulsation. Since the speed of operation is above that at which the color appears to be constant in quality, the residual flicker apparently must be attributed to brightness variations alone.

Let us analyze the phenomena still further, and examine the experimental evidence. Broca and Sulzer[5] and Luckiesh[6] have shown that visual sensations rise and decay at different rates for different colors. In some of their experiments on this point, however, the colored lights were alternated with darkness, whereas in flicker photometers the retina is continuously stimulated. If the different rates of growth and decay had any effect in the flicker photometer as used, that is, if the results of the tests just cited applied to the phenomena occurring there, it would follow that the position for an intensity balance obtained by this photometer would depend the speed of flicker. For example, comparing red and green lights, the ratio of red to green would decrease as the speed increased, and finally reach a constant value. A search of the literature has failed to reveal any evidence that such is the case. The only effect of speed as shown experimentally is to change the range

* While the Kingsbury flicker photometer has been referred to specifically, the theory developed here applies equally well to practically all flicker photometers with the possible exception of the Bechstein photometer referred to above.

** The idea of a pulsating light flux is not necessarily a new idea, though no one else appears to have followed the idea to definite conclusions based on evidence. The nearest approach to such a development is the work of Luckiesh[6], but in it the principal consideration was the effect of light flux wave form on critical frequency.

[5] *Comptes Rendus*, 1903, p. 977, 1046.

[6] *Physical Review*, 4, p. 1, July, 1914.

over which a balance can be obtained, that is, increasing the speed reduces the sensitivity but does not alter the average result.[1] I have recently confirmed this result by measurement of a carbon against a daylight tungsten lamp, the average balance point being practically identical at all speeds.

Dr. E. Karrer and I have recently carried out another test bearing upon this point. Two lamps were color-matched, using a Lummer-Brodhun contrast type photometer. A 180° sectored disk was then rotated in front of one of the lamps at such a speed that flicker was just apparent, and a set of photometric observations was made. Then the speed of the disk was increased to a very high rate and another set of readings taken. Similar observations were made at high and low intensities with the photometer eyepiece covered alternately with deep red and deep green gelatine filters. The balance point at a particular intensity was the same in all cases within about one per cent. Recently it has been called to our attention that Dr. Hyde[7] performed identically the same experiment many years ago, with similar results. The highest intensity used in our experiments was much higher than was available for his tests however, and our results may therefore be considered as an extension of his work to higher intensities. This test proves two things, namely, that the transmission-factor of a sectored disk is independent of the color of the light, and that at speeds at which flicker is just apparent, as in the flicker photometer, the average stimulus for red and green is the same as when the speed of flicker is much too great to cause flicker. Further evidence bearing upon the comparison of flickering and steady lights is given by tests reported by Luckiesh.[6] Summarizing his work he says: "Red and blue-green lights add in the same manner whether by direct superposition or by alternately flickering them as in the flicker photometer when the speed is not lower than that at which flicker is barely apparent." From the various tests which he performed he concludes further: "These experiments indicate quite strongly that the flicker photometer is not affected by the difference in the rates of growth and decay of color sensations."

[7] E. P. Hyde, *Bulletin of the Bureau of Standards*, Vol. II, p. 30, 1906.

The theory developed above does not account for the reversed Purkinje effect which has been observed by Ives[8] and Luckiesh.[9] It is a well known fact that some radical change in visual response takes place at the low level of illumination where the Purkinje effect appears, and hence it would not be surprising if flickering and stationary colored lights should be differently evaluated at very low intensities. It should be noted that all the experimental evidence cited was obtained at illuminations well above this level, and it is not justifiable to assume that results would be the same at those low levels.

I have recently carried out another experiment to test the summation quality of the flicker photometer. (A similar test was made by Ives[10] many years ago.) Three lamps, red, green and blue were mounted in a white lined box with opal-glass window, and so adjusted in intensity that the combined effect was a color approximately the same as that given by the comparison lamp. The brightness of the window was then measured by the flicker photometer for the lamps individually and collectively. The result approximately verified Ives' result that brightnesses measured with the flicker photometer are additive. More extensive tests of this nature are necessary if definite conclusions are to be drawn, however.

The evidence bearing upon this theory of operation of the flicker photometer may then be summarized as follows:

1. In a flicker photometer operated as described there is a pulsation of light-flux in the photometric field when the fields illuminated by the two sources are not of equal brightness. Detection of this pulsation depends on certain factors, the most important being the magnitude and frequency of the pulsation.

2. Color flicker disappears at a lower rate of alteration than brightness flicker, except perhaps when color-differences are very large. That the flicker which remains at higher speeds is not due to color is evidenced by the fact that it can be eliminated at the condition where the color contrast would naturally be expected to be greatest, *viz.*, when the two fields are of aproximately equal brightness.

[8] H. E. Ives, *Phil. Mag.*, July, 1912, p. 149.
[9] M. Luckiesh, *Elec. W'ld.*, March 22, 1913.
[10] H. E. Ives, *Phil. Mag.* 24, 1912, p. 845.

3. The intensity ratio of the two lights compared, as determined by the disappearance of flicker, is independent of the speed of alternation at speeds above the minimum at which flicker can be made to disappear, the only effect of increasing speed being a decrease in sensibility. If the results obtained were influenced by the different rates of growth and decay of visual sensations, it would be expected that results would vary with the speed. Hence it appears that this factor can be eliminated from consideration.

4. The transmission-factor of a sectored disk is independent of the color of the light, even when operated at such a speed that a slight flicker is apparent. Or, expressed in another way, the intensities of successive flashes of light are integrated by the eye irrespective of color.

5. Experiments of Ives, Luckiesh, and others show that the flicker photometer passes the summation quality test which any photometric method must pass in order to be valid as a method of measuring brightness.

In view of the experimental evidence cited it would appear to be very probable that the flicker photometer *does* measure relative brightness as defined above, unless the results are affected by some other factor which has not been considered here and which is not at present apparent.

Some very significant experiments bearing on the operation of flicker and "direct comparison" photometers were performed by Dow[11]. By various tests he showed that the intensity ratio of certain red and green lights depend on the solid angle subtended at the eye by the photometer field. One very striking experiment was the use of a concentric circular field, in which the positions of the red and green lights could be reversed. By reversal of such a field in a Lummer-Brodhun photometer he obtained a difference of 18 per cent in the ratio of red to green. I have recently verified this for my own eye, though I am not sure whether the difference is in the same direction. This shows (as has long been known from other researches) that the retina differs in relative sensitivity to differently colored lights in the central and peripheral regions. Hence the above proof that the flicker photometer measures relative brightness should be qualified to say that the photometer correctly evaluates the relative stimulation, by lights of different

[11]J. S. Dow, *Philo. Mag.* 12, p. 120, 1906.

colors, of the portion of the retina used in the experiments. Evidently its action *cannot* be independent of the observer used, as was thought by the early experimenters, but the results will depend on the observer's sensitivity to lights of different wave-lengths. It should further be emphasized that comparisons of results of tests by flicker and "direct comparison" photometers are not strictly valid unless the angles subtended by the fields are equal, for unless they are equal the instruments are not comparing stimuli of equal parts of the retina. It is not certain that "direct comparison" fields of equal size, one of which was a central spot and annular ring and the other a circle divided vertically, or the more common trapezoidal contrast field, would give identical results in heterochromatic photometry, in fact it seems improbable that they would. Yet none of these have been condemned as giving improper results, and results by each have been accepted without question.

Earlier in this paper the need for specifying the conditions of measurement was stated. The need is probably more apparent now, in view of the experimental evidence cited. Some have taken the stand that "direct comparison" photometers are the only ones which correctly evaluate relative intensities of differently colored lights. On the other hand, experimental evidence[9] shows that the results obtained by any observer using this class of photometers can be varied by varying the conditions of the measurement. How, then, are we to decide which instrument and method gives the *correct* result? There is no way of determining this, and we have been accepting results obtained in any one of a number of ways. The fact that the flicker and "direct comparison" photometers do not exactly agree when lights differing widely in color are compared does not necessarily prove that the former is incorrect; in fact, it has just as much right to credence as the latter has. Since the result obtained by any photometer may be very appreciably different from that of a practical test of the usefulness of the lights in producing vision (assuming that such a test, of sufficient sensitivity, could be devised), some compromise or standardization of conditions of measurements is necessary. It would seem that one of the most important characteristics to be sought after in any method is reproducibility at any time by different groups of observers. All of this has a very

important bearing on so-called "visibility" curves. At best such curves represent relative visibility only under certain definite conditions which are foreign to the conditions of use of the light in everyday life.

Up until this century most photometric work was done with only moderate color-differences, and any photometric method then in use would give fairly satisfactory results. In the present day, with our commercial illuminants extending over a wide range of colors and with greater need for precision, the importance of standardization of instruments and methods, after a thorough study, is very important if reproducible and consistent results are to be obtained. There is still need for much research work on instruments and methods of measurement in heterochromatic photometry. A few of the lines of research which suggest themselves are as follows:

A thorough study of flicker photometers of different types to determine the extent to which brightnesses evaluated by them can be added and subtracted as arithmetical quantities, that is, a study of their summation qualities.

A similar study to determine whether evaluations of brightness by so-called "direct comparison" photometers can be treated likewise, and to what extent.

Comparison of results with the flicker photometer with 2° and 180° fields, and a similar comparison of the other types of photometers if it can be arranged. (An integrating sphere could be used for the 180° flicker field.)

Further study of the flicker photometer, and the Lummer-Brodhun contrast photometer with equally sized fields, with various color differences.

Work on the first two suggestions would do much to clear up the question of the validity of measurements by the two methods, since no method is valid unless it possesses the summation quality.

Having had considerable experience with flicker photometers, I should like to call attention to some important points in the operation of such instruments, especially as practically all that have been sold in this country are mechanically imperfect and need considerable revision to make them satisfactory.

If the photometer is of the Kingsbury type, where the photometer field is viewed through an illuminated diaphragm, this diaphragm should be uniformly white to the edge of the field, and the edges of the hole should be sharp, so that there is no dark ring around the field. In operation the brightness of this diaphragm should be approximately the same as the field or a little brighter, as this gives the greatest sensibility.

When the optical parts are rotated slowly, no shadows or unequally illuminated spots should be apparent in the field. This requires careful adjustment of position of cube and mirrors, and uniform illumination over the whole photometer screen.

The two fields should be visible for equal lengths of time during a complete cycle.

The photometer-head should remain stationary, and intensities should be balanced by moving one of the lamps. This lamp should move with little effort on the part of the observer.

Too large a flicker-field is unsatisfactory, as peripheral flicker persists after central flicker has disappeared.

The greatest trouble with the flicker photometers available is caused by the motor. In order to operate satisfactorily the motor should run smoothly and steadily at or near its rated speed. Hence there must be a large speed reduction ratio between the motor and optical parts. A direct-current series-wound motor with fly-wheel and reducing pulleys giving a reduction of eight or ten to one would probably give the best service. Wire-spring belts are not entirely satisfactory on account of non-uniformity of flexibility, but any other type of belt used should be so arranged that it could be easily tightened.

The flicker photometer is *not* suitable for continuous work, on account of its fatiguing effect, but should be used only for periods not exceeding about an hour. It should find its greatest usefulness in the standardizing laboratory, and in the standardization of color screens for routine work with the contrast photometer.

No photometric method now available is entirely satisfactory when very large color differences, such as a determination of relative intensities of pure red and green, are encountered. The flicker photometer then loses much of its sensibility on account of the high speed required to eliminate flicker. In such cases it is desirable to make the measurements in two or more steps of lower color difference.

DISCUSSION

The papers by Mr. A. H. Taylor and Messrs. Cady and Forsythe were discussed together. See page 598.

PAINTS FOR INTEGRATING SPHERES*

BY A. H. TAYLOR**

In the use of photometric integrating spheres one of the most important details is the white paint used for painting the interior. There appears to be no paint on the market which fulfills all the requirements, and those in use in many laboratories have proved to be unsatisfactory. So far as the author knows only one thorough investigation of this matter has previously been made. It was made by a German photometric commission, the results being published by Utzinger[1]. This commission recommended the use of a paint consisting of (a) a ground "body" paint of which only one coating is required, and (b) a surface paint which should be applied in three coats. The "body" paint consists of lead white or baryta ground into a varnish made up of equal parts by weight of copal and turpentine. The surface paint is made up as follows:—100 parts of zinc white are added to 8 parts of water, and 100 parts of this zinc water paint are then thoroughly mixed with 6 parts of a solution of colorless glue in the proportion of 1 part glue to 5 parts water.

Several years ago the author prepared the plans and assisted in the construction of an 88-in. sphere at the Bureau of Standards. He planned to use the paint recommended by Utzinger, but diligent search failed to find a colorless glue, or a satisfactory substitute.

The requirements for a satisfactory paint for integrating spheres are unusually severe. To be entirely satisfactory it should fulfill the following conditions:

1. It should be perfectly matt, reflecting light in accordance with the cosine law.

2. It should be tenacious and somewhat elastic.

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** Laboratory of Applied Science, Nela Research Laboratories, Nela Park, Cleveland, Ohio.

[1]*Utzinger, Elek. Zeit.*, Vol. 36, p. 137, 1915.
Sci. Abs., B, Vol. 18, p. 375, 1915.

3. The paint should be a pure white, that is, its reflection should be non-selective, and it must not change in color with age or temperature.

4. The reflection factor should be high.

Of these requirements Numbers 1 and 3 are hardest to fulfill. No oil paint is colorless, and such paints will turn yellow with age, especially when used in an enclosed space. Although a perfect diffuser is unobtainable, it is possible to make up a paint which will fulfill this condition closely enough for all practical purposes.

When this paint problem arose, extensive experiments were made in the effort to find or develop a suitable paint. It appeared that the most serious defect of all the commercial paints examined was their color. In order to reproduce approximately the distortion of color which results from multiple reflection in the sphere a test box was made up. It was cubical, with a colorless ground glass window in one side, and contained a small lamp. The reflecting walls were composed of removable cardboards covered with the paint to be tested. In making a test the walls were first lined with black velvet, and the lamp arranged to illuminate the window directly. This window illuminated the screen of a Lummer-Brodhun photometer. The voltage of the comparison lamp was then varied until a color match was obtained. Next the black velvet was replaced with the test cards, the direct light was screened from the window and an effort was again made to obtain a color match.

After a number of samples of commercial "flat white" paints had been tested in this manner, without satisfactory results, an effort was made to develop a suitable paint. In the discussion of a paper presented before this society by Dr. Rosa and the author in 1915, Mr. D. MacFarlan Moore had stated that he had found a zinc oxide paint, using a cellulose lacquer for a binder, to be entirely satisfactory. In his paint use is made of amyl-acetate, which is expensive and very obnoxious because of the toxic effect of the vapor. In an endeavor to avoid the use of amyl-acetate a lacquer was made up by dissolving celluloid and camphor in alcohol. Numerous pigments were tried, most of the experiments being with magnesium carbonate and oxide, zinc oxide and barium sulphate. None of these was found to be non-selective, all except the barium sulphate resulting in a greenish-yellow hue which could

not be color-matched very closely by a change of voltage of the comparison lamp. It was found that the barium sulphate gave the best results in this respect, and although it was selective in its absorption, an almost perfect color-match was obtainable by reducing the voltage of the comparison lamp. Other difficulties were encountered in trying to make up a paint with this pigment and lacquer, and variable results were obtained, so that the effort was finally abandoned.

It was found that a fairly satisfactory paint could be made up with magnesium oxide, but the mixed paint before being applied, gradually turned yellow, a perceptible change taking place within 24 to 48 hours. There was apparently no change in color after it was applied, however.

Although the zinc-oxide paint is somewhat selective in its absorption, it is apparently satisfactory in all other respects, and is now being used in the spheres at the Bureau and elsewhere. Before applying it to the concrete sphere the surface was given a priming coat of a thin solution of cabinetmakers' glue. Waterglass would probably serve equally well. The zinc-oxide paint is prepared as follows:

Prepare a lacquer composed of the following:

Denatured alcohol	100 parts by weight
Camphor	15 " " "
Celluloid (colorless, small pcs.)	10 " " "

Dissolve the camphor in the alcohol before adding the celluloid, using a motor operated stirrer. Add the small pieces of clear, colorless celluloid slowly, while stirring, to prevent them from sticking together or to the walls of the vessel. Continue the stirring (covering the vessel) until all the celluloid is dissolved, which usually requires about ten or twelve hours. This makes a very thick, viscous lacquer. Keep a record of the weights used, so that the alcohol lost by evaporation can be replaced when the celluloid is dissolved.

The paint is prepared as follows:

ZINC OXIDE PAINT.

Cellulose lacquer	4 parts by weight
Alcohol	1 part " "
Zinc oxide	4 parts " "

Add the zinc-oxide slowly to the lacquer and alcohol, stirring constantly. Continue the stirring until a smooth, thick paste is obtained. This requires about one hour or more. Then add slowly about two parts of alcohol and one or two parts of water-white turpentine. If not thin enough, add more alcohol. Use the paint thinner than the ordinary oil paints.

This paint dries very quickly, even on a non-porous surface. and should be brushed out as applied. Care should be taken not to brush over the fresh paint after it has been put on for about fifteen seconds, else the brush will draw the paint. Avoid contact with any water, as water coagulates the paint. Best results will be obtained if drying is retarded by preventing exposure to drafts, etc. In painting a 30-in. metal sphere it has been found best to turn the hemispheres open side up and cover with cloth as soon as the painting is completed. If the paint "checks" add some more camphor. Checking is most often caused on bare metal by applying the coat too thick. If flaking occurs, make the paint less rich in lacquer. Allow about three hours between the first two, and six or seven hours between coats thereafter.

This paint is tenacious, is permanent in color, and has a very high reflection factor, being 94 per cent with one lot of zinc oxide used. The covering power is also good.

The greenish-yellow hue of the sphere window can usually be almost perfectly matched by the introduction of greenish glass, such as ordinary window glass, on the comparison lamp side.

This paint has been found to be very useful around the laboratory for other purposes where a very high reflection factor is desired. The diffusion is not perfect, but is sufficiently so for use in integrating spheres.

It may not be amiss to note that a somewhat lower reflection factor is desirable in spheres used in life tests of incandescent lamps where the blackened lamps may absorb an amount of light appreciably different from that absorbed by the clear lamps used in standardizing the sphere.

DISCUSSION

The papers by Mr. A. H. Taylor and Messrs. Cady and Forsythe were discussed together. See page 598.

INTERLABORATORY PHOTOMETRIC COMPARISONS OF GAS-FILLED TUNGSTEN LAMPS*

BY W. E. FORSYTHE AND F. E. CADY**

Just when those interested in the subject of photometry thought the time had arrived when the measurement of incandescent lamps had reached a fair degree of accuracy and efforts were being concentrated on the improvement of primary standards of light to make them constant and reproducible to within a few tenths of one per cent, the gas-filled tungsten incandescent lamp was developed and caused a revolution in photometric procedure.

It was early found that the mean horizontal candle-power of these lamps changed if they were rotated and became a function of the speed of rotation. Since a determination by the point-by-point method was impracticable in commercial work, the mean spherical candle-power was adopted as the quantity to be measured while the lamps were rated in lumens. This change was the more easily accomplished because it was found that the Ulbricht sphere was a practical instrument which could be adapted even to factory use.

The gas-filled lamp by reason of the higher temperature of its filament and consequent "whiter" character of its light brought in another complication in its photometry, that is, its color. While the difference in color, photometrically considered, between a carbon lamp and a vacuum tungsten lamp was bad, the gas-filled lamp greatly increased the difference and until a primary standard of a near approach in color has been adopted, the question of color photometry will remain a factor in measurements of the high wattage lamps.

Reports of comparative photometric tests of incandescent lamps have been made to the Illuminating Engineering Society on several occasions, and in order that such information should be as complete as possible, it was thought that it might be help-

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**Laboratory of Applied Science, Nela Research Laboratories, Nela Park, Cleveland, Ohio.

ful to have duplicated in other laboratories a set of measurements made by the authors for another purpose at Nela Research Laboratory on the mean spherical candle-power of various types of gas-filled lamps. The following photometrical laboratories very kindly consented to cooperate in such a test: The Research Section and Testing Section of the Engineering Department, National Lamp Works, designated hereafter by R. N. L. W. and T. N. L. W.; the Photometric Laboratory of the Westinghouse Lamp Company, designated by W. L.; the Electrical Testing Laboratories, designated by E. T. L.; the Edison Lamp Works of the G. E. Co., designated E. L. W.; and the Bureau of Standards, designated by B. S. At this point, the authors desire to express their appreciation of the courtesy shown by the above laboratories in making the measurements recorded in the test.

Inasmuch as no method of color photometry has yet been generally accepted as standard, and as the lamps themselves were ordinary commercial lamps, it was decided to ask each laboratory to photometer them as they would if they had been sent in for a regular commercial test and in their report to give information on the following points:

(1) A complete description of the standards used and where they were obtained.

(2) What method was used, if any, to overcome color differences involved.

(3) The number of observers participating and whether they were regular operators or special.

Replies received from the laboratories were as follows:

Research Section, National Lamp Works:

"Our records show that these lamps were photometered against four 500-watt Type C lamps which we made up directly from a set of primary Bureau of Standards lamps. Our photometer was set up at a color match with these 500-watt lamps operating at approximately 0.85-watt per spherical candle. No correction was made for the difference in color between this 0.85 efficiency and that of the lamps which we photometered for you. The readings which we forwarded to you are an average of three observers taken on our 54-in. sphere."

Testing Section, National Lamp Works:

"The reading on these lamps by Testing Section were obtained in our 100-in. sphere. The readings reported in my letter of April 18, were the averages of two separate sets of observations by a single regular operator. These two sets of readings were taken on different days and consisted of three readings each.

The standards used were calibrated and supplied to us by our Research Section. The photometer 'check up' was accomplished by the substitution method. The standards in 'checking up' for reading the 500-watt lamps and above were 500-watt—115 volt—Type C lamps of regular construction and for reading the 100-watt Type C lamps, 100-watt—115 volt—Type C standards of regular construction were used. Three standards and two check lamps (checking standards) were used in each 'check up.'

The comparison lamp used in 'checking up' and making all readings was a 60-watt Type B lamp. Color correction screens were used to overcome color differences."

Westinghouse Lamp Company:

"1. The following standards were used for the test:

100 watt	100 volt grade
300 watt	100 volt grade
500 watt	100 volt grade
750 watt	100 volt grade
1000 watt	100 volt grade
200 watt	220 volt grade

These lamps were furnished us by the Electrical Testing Laboratories after comparison with their standards from the Bureau of Standards. The standard lamps were operated slightly below normal operating efficiency and a 100-watt vacuum lamp was used in the comparison position. There was, therefore, quite a considerable color difference involved both on the initial standardization of the photometer and on the actual measurements.

2. No method for eliminating or overcoming color differences was used. This is in accordance with our custom since all five of the operators involved in this kind of work have been consistently trained by this method. This is at variance with our procedure in the factory where color screens are used.

3. Two observers were used on this particular test. They were chosen from the regular life test photometry staff as the most experienced of the group."

Electrical Testing Laboratories:

"1. The Type C lamps standardized at the Electrical Testing Laboratories were used when standardizing the photometer to read the gas-filled lamps submitted to us for test.

2. A color filter was placed between the comparison lamp and the photometer to change the color of the Type B comparison lamp to that of the Type C lamp. The photometer was standardized with Type C lamps.

3. Two regular photometer operators made photometric measurements."

Edison Lamp Works:

"1. In the testing, the reference standards used were made by the Bureau of Standards and with the exception of the stereopticon type were of the types under test.

2. No effort was made to overcome color differences.

3. Two regular observers participated in the test."

Nela Research Laboratories:

1. At Nela Research Laboratories, the standards used were six 500-watt gas-filled tungsten lamps of the regular commercial type, carefully chosen and seasoned. They had been standardized at the Bureau of Standards for mean-spherical candle-power. During the tests, measurements were made on a standard lamp before and after each of the five groups of lamps.

2. No method was employed to overcome the color difference between the standards and the lamps under test, but a color screen was used on the comparison-lamp side of the photometer so that there was an approximate color match when the standard lamps were being measured.

3. Measurements were made by two experienced observers using the regular 80-in. sphere and an ordinary Lummer and Brodhun contrast photometer.

Bureau of Standards:

"1. These lamps were measured for spherical candlepower in an 88-inch integrating sphere. The standards used are a group of 500-watt gas-filled lamps, the values of which are the basis of all gas-filled standardization work done by this Bureau.

2. No attempt was made to avoid the color differences encountered. A color match was obtained when reading the standards which operates at about 0.82 wpsc.

3. The values given are the results of measurements by five regular observers."

From the above statements it will be seen that in some of the laboratories color differences were minimized by using standard lamps of the same efficiency as those under test. In others color screens accomplished the same result. In two instances a single set of standards was used, thus involving the full color differences. In studying the results of the intercomparison, these points together with the other facts given in the statements from the various laboratories should be taken into consideration.

The lamps tested consisted of three each of the regular commercial 100-watt, 500-watt and 1000-watt, the 1000-watt

Lamps Nos. 1 to 5—No. 1, [illegible]-watt gas-filled; No. 2, [illegible]-watt [illegible]; No. 3, 900-watt movie; No. 4, [illegible]-watt gas-filled and No. 5, [illegible]-watt gas-filled.

stereopticon type, and the 900-watt lamp for moving-picture projection; all tungsten in gas-filled bulbs. A photograph of the individual types is shown in the illustration 1. It should be noted that of the various sizes and types of gas-filled lamps, the 500-watt lamp, when properly seasoned, has been found to be sufficiently constant and dependable in its candle-power value to be used as a secondary standard and as such it is employed in some laboratories. In order to give some idea of the variations in efficiency and the color differences involved in this test, Table 1 has been prepared, which includes for purposes of comparison the 4-w. p. h. c. carbon lamp and the 1.25-w. p. h. c. tungsten.

TABLE I. EFFICIENCIES AND COLOR TEMPERATURE OF THE VARIOUS LAMPS.

Lamp.	Specific consumption	Color temperature Degrees Kelvin.
Carbon	4 w. p. h. c.	2080
Tungsten	1.25 w. p. h. c.	2400
100 watt gas-filled	1. w. p. s. c.	2745
500 watt gas-filled	0.72 w. p. s. c.	2835
1000 watt gas-filled	0.62 w. p. s. c.	3010
1000 watt stereopticon	0.52 w. p. s. c.	3185
900 watt movie	0.46 w. p. s. c.	3290

By color temperature is meant that temperature at which a black body must be operated so that its emitted light has the same integral color as the lamp under consideration. It will be seen that the color difference, as indicated by the color temperatures, between the 1.25-w. p. c. tungsten and the 500-watt gas-filled and again between the 500-watt and the movie lamp is not very different from that between the 4-w. p. c. carbon lamp and the 1.25-w. p. c. tungsten lamp.

Another indication of color differences was obtained by measurements with a blue glass filter. This glass is a standard used to produce an approximate color match between the 4-w. p. c. carbon and the 1.25-w. p. c. tungsten. To go from the 1.25-w. p. c. tungsten to the movie lamp it was necessary to make two

TABLE 2. CURRENTS OR VOLTAGES OBTAINED BY THE DIFFERENT LABORATORIES AT THE GIVEN VOLTAGES OR CURRENTS.

	VOLTS	N. R. L.	R. N. L. W.	T. N. L. W.	N. R. L.	W. L.	E. T. L.	E. L. W.	N. R. L.	B. S.
100-watt		I	I	I	I	I	I	I	I	I
1	112.5	0.89	0.89	0.891	0.895	0.89	0.888	0.89	0.889	0.892
2	115.4	0.868	0.869	0.871	0.874	0.868	0.867	0.867	0.868	0.868
3	116.1	0.859	0.857	0.858	0.861	0.856	0.857	0.858	0.858	0.857
500-watt										
1	116.6	4.321	4.319	4.33	4.322	4.32	4.31	4.30	4.313	4.32
2	117.3	4.31	4.309	4.32	4.310	4.32	4.30	4.30	4.301	4.30
3	114.6	4.194	4.199	4.21	4.202	4.21	4.26	4.25	4.194	4.19
1000-watt										
1	117.1	8.726	8.705	8.70	8.708	8.71	8.70	8.69	8.69	8.68
2	117.9	8.79	8.799	8.80	8.793	8.80	8.79	8.78	8.788	8.78
3	114.5	8.759								
Stereopticon										
1	115.9	8.76	8.751	8.76	8.734	8.75	8.75	8.75	8.744	8.75
2	116.95	9.44	9.428	9.45	9.408	9.40	9.42	9.43	9.436	9.41
3	117.55	8.75	8.724	8.74	8.707	8.725	8.71	8.71		
Movie		V	V	V	V	V	V	V	V	V
1	30 A	31.65	31	31.75	31.7	31.7	31.96	31.9	32.11	31.8
2	30 A	31.80	30.64	30.35	31.8	30.3	30.75	30.7	30.85	30.6
3	30 A	30.63	30.69	31.35	30.7	31.2	31.56	31.5	31.85	31.55

TABLE 3. VALUES OBTAINED BY VARIOUS LABORATORIES OF MEAN SPHERICAL CANDLE-POWERS REDUCED TO LUMENS.

	VOLTS	N. R. L.	R. N. L. W.	T. N. L. W.	N. R. L.	W. L.	E. T. L.	E. L. W.	N. R. L.	B.S.
		L	L	L	L	L	L	L	L	L
100-watt										
1	112.5	1280	1280	1295	1310	1315	1280	1320	1275	1282
2	115.4	1250	1230	1257	1275	1295	1250	1280	1240	1238
3	116.1	1310	1275	1295	1315	1320	1300	1330	1290	1287
500-watt										
1	116.6	9000	8950	9140	9050	9250	8870	8900	9050	9078
2	117.3	8950	8950	9120	9100	9250	9000	9000	9050	9060
3	114.6	8200	8200	8320	8350	8550	8860	8950	8300	8320
1000-watt										
1	117.1	18750	18850	19150	18900	19350	18760	19300	19000	18970
2	117.9	18850	19000	19160	19050	19550	19000	19500	19200	19100
3	114.5	18350								
Stereopticon										
1	115.9	21750	22150	22600	21600	22100	22100	22150	21850	22600
2	116.95	27000	27200	28030	27000	27150	27000	27950	27450	28000
3	117.55	21350	21800	22630	21600	21900	21800	22450		
Movie										
1	30 A	25900	26250	26850	25400	25650	25800	25650	26350	26500
2	30 A	23900	24550	24870	23850	23900	24000	23400	23950	23900
3	30 A	25500	25950	26320	25200	25150	25800	25750	26000	26300

steps; the first carrying the color match slightly above that necessary for the 500-watt lamp, and the second step carrying it slightly beyond the movie lamp. The above data show that the old problem of heterochromatic photometry which arose when it became necessary to measure tungsten lamps in terms of carbon lamps standards is still present even though the 500-watt gas-filled lamps are used as standards to measure other high efficiency tungsten lamps.

The lamps were first photometered at Nela Research Laboratories then sent to the Engineering Sections of the National Lamp Works, and, re-photometered at N. R. L. before being sent to the remaining laboratories. On account of the brief time available it was thought best to have the lamps returned to and photometered at N. R. L. before they were sent to the B. S. and this explains why the results from the B. S. appear at the end of the tables.

The data are given in Tables 2 and 3. In the first column are the lamp designations, and these are followed by the assigned voltages or currents. Table 2 shows the current or voltage values while the mean spherical candle-powers reduced to lumens are given in Table 3. The order in which the data from the various laboratories are given is the same as that in which the lamps were sent to be photometered.

In view of the relatively large differences in color between the "movie" lamps and the others and the marked difference in the filament shape and supports, the agreement in the candle-power values is somewhat surprising.

There are so many variables involved in a test of this character—the uncertainties and changes in the lamps themselves due to contacts, to convection currents in the gas, structural changes in the filament, etc., the color differences, the different sizes of spheres, the different standards, and the number and character of the observers,—that it is hard to draw any definite conclusions. But it would certainly seem that with the possibilities involved in so many variables, the concordance of the laboratories is very satisfactory.

DISCUSSION

The papers by Mr. A. H. Taylor and Messrs. Cady and Forsythe were discussed together.

D. McFarlan Moore: The paper on "Paints for Integrating Spheres," is a gratifying surprise to me in that it seems to corroborate the claims made for the zinc oxide paint some years ago. The story of the development of this paint would prove interesting, but time does not permit. However, it extends from 1894 to to-day. At the time I presented a paper to the I. E. S. on a new form of color matching lamp, photometric tests were made upon this vacuum tube lamp, and it was discovered the results were the same without the reflector. This would seem to indicate that this paint was non-selective in its absorption. It has proven entirely satisfactory in various laboratories throughout the country, and in fact, throughout the world.

This paper indicates in order to avoid the toxic effect upon the painter applying the paint, it was desirable to change the formula for preparing cellulose lacquer. It is interesting to know that we had some difficulty with that toxic effect, especially when a painter was trying to paint the inside of an 80-inch sphere, but we obviated that by using an electric fan. Before a substitute for the amyl-acetate was found, we used alcohol and then we discovered that it was necessary to use turpentine. I thought the problem had been solved, in fact, to such an extent that quite a large number of the color-matching lamps were sent to Europe. Some of them came with this particular paint in which the amyl-acetate had been substituted by them for the alcohol.

However, after a period of about two years, it was found that this paint turned yellow and was not satisfactory, therefore, and then the specifications were issued. The order was issued that under no circumstances was that formula to be interfered with, and under no circumstances any turpentine to be used with this photometric paint. Unless the paint that Mr. Taylor describes has had at least two years of life, I have reason to question whether an advance has been made.

C. L. Dows: As a representative of one of the laboratories listed in this photometric comparison, which Mr. Cady has just given, I have been keenly awaiting the results of the Bureau of Standards. Since obtaining these values a few moments ago from Mr. Cady, I have been making some rapid calculations, and find that, with the exception of the stereopticon lamps, we are in agreement with the Bureau by about one-half per cent.

The stereopticon lamps afford a chance for further investigation if time permits because only one other laboratory really checks the Bureau, the remaining laboratories agreeing fairly well among themselves but running about 2.5 per cent. below the Bureau.

The following Table has been prepared showing the per cent variations on individual lamps, considering the Bureau as standard; it gives a good idea of the ability of different photometric laboratories to check the Bureau of Standards in a test of this kind.

TABLE 4. PER CENT DIFFERENCE OF EACH LABORATORY FROM BUREAU OF STANDARDS VALUES AS BASE,—INDIVIDUAL LAMPS.
LAMPS READ AT SAME VOLTS OR AMPERES BY ALL LABORATORIES.

	N. R. L.	R. N. L. W.	T. N. L. W.	N. R. L.	W. L.	E. T. L.	E. L. W.	N. R. L.	B. S.
100 watt									
1	—0.16	—0.16	+1.01	+2.18	+2.57	—0.16	+2.96	—0.55	0
2	+0.81	—0.81	+1.37	+2.82	+4.43	+0.81	+3.22	0.00	0
3	+1.79	—0.93	+0.62	+2.18	+2.56	+1.01	+3.34	+0.23	0
Avg.	+0.81	—0.63	+1.00	+2.39	+3.19	+0.55	+3.17	—0.11	0
500 watt									
1	—0.88	—1.43	+0.66	—0.33	+1.87	—2.31	—1.98	—0.33	0
2	—1.21	—1.21	+0.66	+0.44	+2.09	—0.66	—0.66	—0.11	0
3	—1.44	—1.44	0.00	+0.36	+2.76	+6.49	+7.57	—0.24	0
Avg.	—1.18	—1.36	+0.44	+0.16	+2.24	+1.17	+1.64	—0.23	0
1000 watt									
1	—1.31	—0.79	+0.79	—0.53	+1.84	—1.26	+1.58	0.00	0
2	—1.31	—0.52	+0.31	—0.26	+2.36	—0.52	+2.09	+0.52	0
3	......	......	......	......	......	......	......	......	....
Avg.	—1.31	—0.66	+0.55	—0.40	+2.10	—0.89	+1.84	+0.26	0
1000 watt Stereopticon									
1	—3.76	—1.99	0.00	—4.42	—2.21	—2.21	—1.99	—3.32	0
2	—3.57	—2.86	+0.11	—3.57	—3.04	—1.43	—0.18	—1.96	0
3	......	......	......	......	......	......	......	......	....
Avg.	—3.66	—2.42	+0.06	—4.00	—2.62	—1.82	—1.08	—2.64	0
900 watt Movie									
1	—2.26	—0.94	+1.32	—4.15	—3.21	—2.64	—3.21	—0.57	0
2	0.00	+2.72	+4.06	—0.21	0.00	+0.42	—2.09	+0.21	0
3	—3.04	—1.33	+0.08	—3.99	—4.37	—1.90	—2.09	—1.14	0
Avg.	—1.77	+0.15	+1.82	—2.78	—2.53	—1.04	—2.46	—0.50	0

E. C. CRITTENDEN: There has been considerable doubt as to the reliability of gas-filled lamps as standards of candlepower, and this intercomparison makes an important and much needed addition to our knowledge of the situation existing in the practical measurement of such lamps. Messrs. Forsythe and Cady deserve much credit for carrying the job through, and the results obtained are extremely satisfactory as indicating a really surprising degree of agreement between most of the important laboratories which have occasion to make measurements on gas-filled lamps.

The statements in the paper with regard to the color differences covered in the measurements are correct, but a hasty reading and reference to Table I might give rise to a misconception on that point. These comparative measurements can not be considered as showing a satisfactory state of affairs in regard to the step up from the fundamental carbon standards, because they do not involve any comparison of results obtained by different laboratories in making this step. All the measurements are based on gas-filled standards, whose values in turn are derived from a group of 500-watt lamps adopted as reference standards at the Bureau of Standards. If each laboratory went back independently to the carbon standards or even to vacuum tungsten standards, it is not at all likely that so good an agreement would be shown.

As indicated in th paper, no method of color photometry has yet been generally accepted as standard. A really satisfactory state will be reached only when agreement on a method is obtained and standards are established in accordance with it. Such an agreement must, however, be a matter of international consideration. Our friends abroad are now taking an active interest in the problem, and there is a prospect of a more or less definite settlement of the question, but this will take some time. The difficulty has been a pressing one with us for several years, and in the absence of a general agreement it has appeared best to establish secondary reference standards which would at least bring about uniformity of lamp ratings in this country. Such standards were therefore carefully evaluated several years ago by methods which we believe make it possible to check their values precisely and thus to maintain a uniform value for the unit. Fortunately

the results reported by Messrs. Forsythe and Cady indicate that this uniformity is actually being obtained in practice to a very satisfactory degree.

G. C. COUSINS: I would like to ask Mr. Taylor a question regarding the white field surrounding the photometric field in the flicker photometer. We have been working with the Ives-Kingsbury test solutions and especially with the blue there is a very annoying after image due to the contrast of the white field with the resultant blue light from the photometric field. Has that any effect on the precision or accuracy of the use of the flicker photometer?

A. H. TAYLOR: In this paper you will note that I give Mr. Moore credit for the first suggestion to us regarding a cellulose lacquer paint, although I neglected to speak of this in orally presenting the paper. I have successfully made up a paint similar to that for which he furnished me the formula, but early decided to avoid the use of amyl-acetate if possible, mainly on account of its toxic effect. With regard to this toxic effect, I was told that several years ago some one was overcome by the amyl-acetate fumes while painting a sphere at the Leeds and Northrup factory in Philadelphia.

In order to avoid the use of amyl-acetate we decided to use alcohol, which is also a solvent of celluloid and camphor. One big factor in its favor is its lower cost, as it costs only about one-tenth as much as an equal volume of amyl-acetate.

The amyl-acetate also has a more pungent odor than the alcohol, and seems to remain in the air longer. While the alcohol and camphor fumes are not pleasant, they are not toxic. At the Bureau of Standards we have found that a man could paint the entire inner surface of an 88 inch sphere without coming out for fresh air until the job was complete, and without any ill effects.

As to the selectivity of the paint, the sphere test is a very severe test of that. If there is any selectivity it will show up when the paint is used for painting integrating spheres. I have not found any pigment that does not have a certain amount of selectivity. The turpentine which is used in the paint is used only to retard drying, and can actually be left out entirely. As a matter of fact,

I do leave it out a considerable part of the time, so it can be left out without any bad effects, but it makes it a little easier to apply if you put it in.

Now as to the color change: I have not had a test over as long as a period as Mr. Moore spoke of. If I remember correctly the test I made extended over a period of about three months. I could not detect any color change in that length of time with samples exposed to direct sunlight every day and with other samples wrapped up and kept in the dark.

P. S. Millar: How often do you repaint spheres?

A. H. Taylor: That depends on conditions, but I usually judge by appearances as to when repainting is needed. This is much less than two years, however. A regular schedule of repainting, based on experience, is desirable, as the matter may otherwise be neglected.

This paint will withstand fairly high temperatures without discoloration. I recently had occasion to solder a brass lug on the outside of a small copper sphere painted with it, and heated the outside with a gas flame sufficiently to melt the solder and do the job. I then found that the paint inside apparently had not been affected in any way. It probably would be discolored by temperatures not much higher, however.

In reply to the question regarding the effect of the color of the surrounding field in the flicker photometer, I seriously doubt that it does affect the results, though I am unable to speak from experience on this point. I have no doubt that this has been investigated, though I do not recollect having seen anything in print regarding it. If it has not been investigated it should be.

F. E. Cady: In connection with the information concerning paint for integratng spheres it might be well to call attention to a recent article by Pfund on the color characteristics of white paints in which he points out that by the addition of a trace of lamp black such paints may be made almost non selective. The paper was published in the Proceedings of the American Society of Testing Materials, **20**, No. 2, page 440, 1920.

On page 576 in a note at the bottom of the page the use of the term "direct comparison" is rather questioned. It would seem to me quite probable that this expression arose from the fact that in

photometers of this type the two parts of the field are presented simultaneously and hence directly in contrast to the arrangement of the flicker photometer where the two parts of the field are presented alternately. The analogy to direct and alternating currents of electricity is self evident.

Mr. Crittenden's point is well taken and I am sorry that I gave that impression. At the same time it should be noted that as far as we know in only one laboratory were standards used of a rating higher than 500 watts. Since the color difference between the 500 watt lamp and the movie lamp is not very different from that between a 1.25 w. p. c. tungsten vacuum lamp and the 500 watt gas-filled lamp. there is a chance to compare roughly, the results of the different laboratories with this color difference even though the standards may all have been obtained from the same source.

B. S. WILLIS (*Communicated*): In preparing lacquer after Mr. Taylor's formula at the Bureau of Standards, it has been found necessary to use alcohol which is at least 95 per cent pure (190 proof), otherwise the water present will prevent the alcohol from dissolving the celluoid. In one case when 80 per cent alcohol was accidentally substituted for the better grade the mixture was stirred for twenty-four hours, at the end of which the liquid was not perceptibly thickened and the celluloid was not dissolved to any extent. A little of the 80 per cent alcohol was added to a sample of lacquer made up with high-proof alcohol and coagulation occurred similar to that which takes place when water is added.

Another factor which might cause trouble is the denaturant. There are some forty formulas used for denaturing alcohol and some of them might cause trouble. The alcohol used at the Bureau of Standards has been denatured with methyl alcohol.

LIGHTING FOR THE MANUFACTURE OF CLOTHING*

BY A. B. ODAY AND R. W. PEDEN**

Under the heading of the manufacture of clothing may fall the production of high grade articles made to special measure, ready-to-wear high grade goods, low-priced coarse laborers clothes, etc. The establishment itself may vary from the modern tailoring establishment to the dark alley sweat shop. Thus we have in the total a great industry with largely diversified working conditions and a wide variety of kinds and classes of goods and materials, with a corresponding number of processes and exacting requirements.

As is true in nearly all large industries, the clothing industry has enjoyed rapid strides in the development of new and better machinery, as well as in the methods of operation; and to-day, even the most insignificant factory or shop is equipped with much up-to-date apparatus. This progress is all the more noteworthy when we stop to consider that it is only a comparatively short time since each family made most of its own clothing by hand from the raw material.

It is natural to assume or expect that an industry which has been so progressive in the development of machines and labor-saving devices, would be equally progressive in accepting modern methods of artificial illumination. However, from the experience encountered by the writers, it is in general, several years behind others in this respect.

In an endeavor to determine the present practice of lighting in clothing factories, an investigation was conducted which included an inspection of approximately 100 factories. An endeavor was made to visit factories covering the manufacture of as large a varity of clothing as possible, also those in several different localities. Factories representing a large variety of product were encountered including underwear, coats, suits, hats, collars, corsets, brassieres, gloves, stockings, ties, waists, shirts, sweaters, furs and overalls.

*A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

**Edison Lamp Works of the General Electric Co., Harrison, N. J.

Fig. 1 shows graphically the results of this investigation with regard to the lighting conditions analyzed as to lamps and power consumption. equipment and systems of illumination employed. Under the heading of lamps and power consumption, it will be noted that, while nearly all were using Tungsten-filament lamps, 86 per cent were using a type of lamp unsuitable for obtaining the most effective and economical results; 22 per cent were using

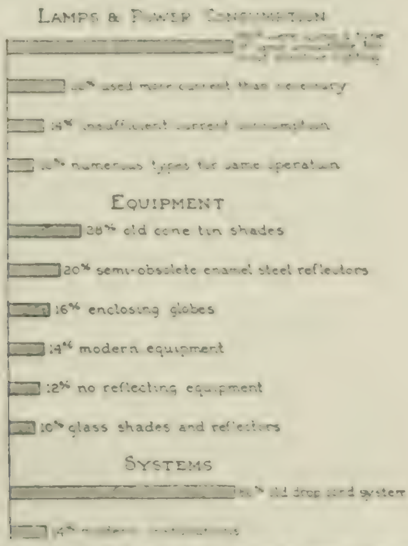


Fig. 1.—Data obtained on the lighting conditions in over 100 clothing manufacturing establishments.

sufficient power, which, if properly applied would have produced adequate illumination; 14 per cent would require greater power consumption to produce adequate lighting; 10 per cent were using a variety of types and sizes of lamps for corresponding operations and showed that no effort whatever had been made in the way of standardization.

With regard to the type of equipment employed, 28 per cent were using antiquated tin shades; 20 per cent semi-obsolete steel reflectors; 16 per cent opalescent enclosing globes; 14 per cent were using modern equipment; 12 per cent used no reflecting equipment whatever; 10 per cent were using inefficient and obsolete glass shades and reflectors.

Under the heading "systems of lighting," it will be noted that 86 per cent were found to be using the old drop-cord system, whereas 14 per cent were using a fairly modern installation. It should be borne in mind, however, that this analysis embraced only the larger factories. As a matter of fact, an endeaver was made to locate factories which gave promise of a reasonably good lighting installation. If the small factories had been included, it is certain that a much smaller percentage of installations classed as "good" would have been noted.

All of us interested in lighting will recall riding or walking through the garment manufaturing center of a large city, and noticing the lighting conditions under which the operators work. Many plants are still using the open-flame gas jet. However. these are rapidly being supplanted by some form of modern lighting. It is quite common to see bare unshielded electric lamps in sizes ranging from 25 to 300 watts, either close to the ceiling or suspended from the ceiling by drop cords, near the eyes of the operator. This is particularly true of the smaller sweat-shop variety of factory.

If the humanitarian side alone is considered, improvement of these conditions represents a work that is well worth while, but a large majority of these factories are so small that the amount of business to be obtained would scarcely make them attractive to a commercial organization, and therefore, little improvement can be looked for from this source.

An educational campaign over a period of time, coupled with local, state and federal legislation, making certain improvements mandatory, are sources from which greatest results may be expected. In states where industrial lighting codes are in force, a great amount of good has already been accomplished.

The purpose of this paper is not so much to describe the type of equipment being employed in the majority of factories at the present time, but rather to recommend what, in our opinion, meets the requirements in a satisfactory and economical manner. utilizing modern equipment intelligently.

TYPE OF LIGHTING

Modern lighting as applied to the clothing industry may be divided into three general classes, namely:

(1) Modern illumination employing lighting units uniformly spaced and hung fairly high at a uniform distance above the floor.

(2) Localized general illumination, employing a hanging height corresponding approximately to that used for general illumination, with the lighting units located with reference to the working position.

(3) A combination of local and general illumination, employing individual lamps located close to the working points, utilizing relative low wattage tungsten lamps and small steel reflectors, this illumination being supplemented by a medium intensity of general illumination from overhead units.

All three of these systems find application in the manufacture of clothing, and the first consideration in laying out an installation is the selection of a system which will produce the best results. In making this selection, the main point to be considered is the nature of the work to be done.

DISTRIBUTION

Perhaps in no other industry is the distribution of light of greater importance than in the manufacture of clothing. In a large majority of operations encountered, shadows cast by machine parts or operators may be extremely objectionable and annoying. This is especially true where work is being done on fine material and visual perception has a definite bearing on the quality of work produced. In view of the exacting conditions encountered, particular care must be exercised in designing an installation so that the distribution of light for a particular operation will adequately meet the requirements.

There is a tendency on the part of some of the factory owners to attempt to utilize a small number of relatively large lamps rather than a greater number of smaller units on account of the lower wiring cost, and uneven, "spotty" lighting is the result.

Owing to the diversified requirements, the clothing industry, calls for a wide range of intensity. For instance, in the shipping room, an intensity of 4 ft-c will be bound to give fairly good satisfaction, while in the sewing room an intensity of 20 to 50 ft-c at the needle point may be required.

Whenever it is possible to do so in the clothing factories, it is recommended that the system of general illumination be employed. In other words. if the required intensity can be economically produced by the system of general illumination, such a system is recommended. If, on the other hand, the economic limit is passed before the intensity has reached the necessary point, a localized general system should be employed, with recourse to a combined local and general system, when the limit has been reached with the localized system. Hence, it will be seen that with the diversified requirements, the theoretical proper intensity of illumination will vary for each factory and for each class of work being carried on, and consequently it will be difficult to set a difinite limit. However, experimentation has proven that certain intensities which come well within the economic limits of good lighting, give beneficial results from every viewpoint, and therefore, recommendations are based upon these figures.

TYPE OF REFLECTORS

While forms of indirect lighting produce a very desirable character of illumination for many operations in the clothing factory, it is seldom employed, due to the higher operating expense. As a result, direct lighting fixtures are considered more applicable. The types of direct lighting units which find application are the standard dome, deep bowl steel, prismatic glass, opalescent glass, mirrored glass and various forms of glass and combination metal and glass enclosing and semi-enclosing units. All of these types, under proper conditions, will produce satisfactory results. However, it is felt that from the standpoint of economy, distribution, maintenance and efficiency, etc., that the standard* dome reflector, especially when equipped with the bowl enameled gas-filled tungsten lamp, will find most universal application.

*The dome herein called "standard" is the type standardized by the reflector and lamp manufacturers.

APPEARANCE

While not of paramount importance, the appearance of a factory, is demanding more and more attention. Of the factors which add to or detract from the appearance of the interior of a clothing factory, one of the most important is the lighting installation. A multiplicity of fixtures and drop cords hung in a haphazard manner at non-uniform hanging heights, employing various types of reflectors and lamps, produce a general appearance which is far from pleasing to the eye. On the other hand, an installation which is uniform throughout, adds to the attractiveness of the interior and creates a favorable impression on the minds of visitors and workers. Circumstances, however, do not warrant the introduction of highly decorated fixtures, as it is neatness and uniformity rather than decoration which counts.

The processes in clothing manufacture are briefly outlined below with indications of the lighting requirements, both as to system and intensity. The more or less standard methods of producing the illumination for the different processes, are given, following this analysis.

REQUIREMENTS FOR INDIVIDUAL OPERATIONS

SEWING (MACHINE)

The requirements in a sewing room are very diversified. The type of machines, the quality of the work being done, the color of the goods, color of walls and ceilings, and the liability to accumulate dust must all be considered in deciding upon and laying out installations.. It is, therefore, obvious when one considers the variation in these factors that no particular system can be selected for universal use in this particular department.

The two main positions at which light is required on the sewing table are, first, at the side of the machine where the goods lie prior to being sewed together, and second, at the needle point. For the former a medium intensity of illumination will suffice. The requirements are that adequate illumination be provided so as to make it possible for the operator to distinguish between different pieces of goods and also between the different parts of the same piece. It is obvious, of course, that a greater amount of

illumination will be necessary when work is on dark goods rather than light. Owing to the unsymmetrical arrangement of the goods there is a considerable liability of shadows being produced, hence well diffused, properly distributed illumination is essential if the vision of the operator is to be quick and sure. For this work a system of general illumination will be found applicable.

The light at the needle point, however, must be of a high intensity. A condition is seldom encountered where illumination below 8 ft-c. in intensity will prove satisfactory, and in many cases it is advisable to have the intensity as high as 50 ft-c. As mentioned before, the color of the goods and the fineness of the

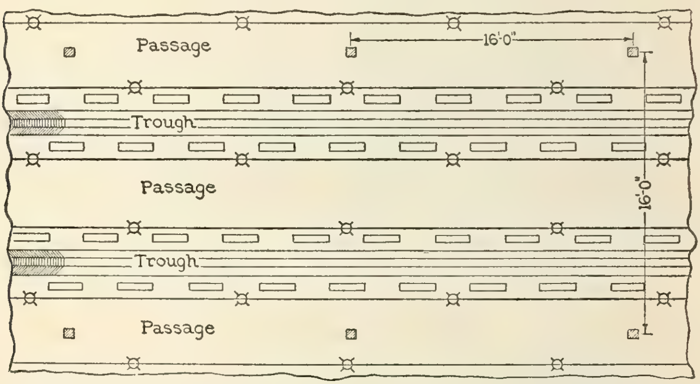


Fig. 2.—Localized general illumination with 100-watt bowl enameled type C lamps in standard dome reflectors hung from 4 to 6 ft. above the table for machine sewing, coarse work.

operation are deciding factors with regards to the amount of illumination necessary. Where the conditions of the work are of an ordinary nature, 8 to 12 ft-c. of illumination will produce fairly good results. Illumination of this character can be produced satisfactorily by an overhead system of general or localized general illumination. Layouts applicable for this type of lighting are shown in Figs. 2 and 3. With such a system the light comes from all directions and only very light shadows are caused by the machines, operators, etc. The system as shown in Fig. 2 is suitable for work where only a comparatively low intensity is required, the effect by night of such an installation is shown in

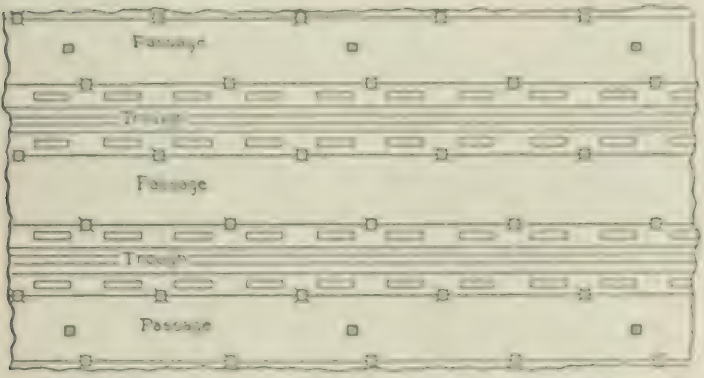


Fig. 3.—Localized general illumination with 150-watt bowl enameled type C **lamps in** standard dome reflectors **hung** 6 ft. above the table for machine **sewing, medium fine work.**

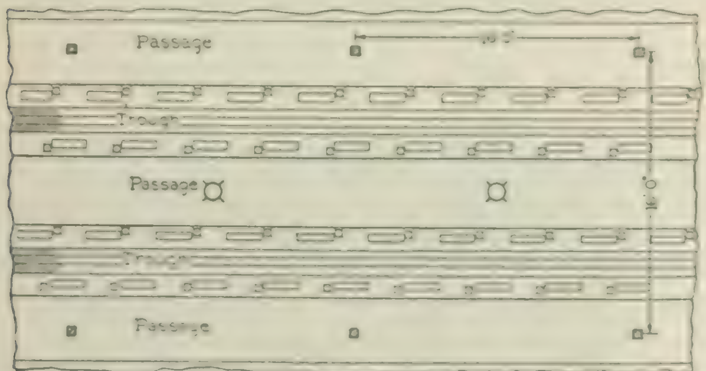


Fig. 4.—Plan of sewing machine tables with lighting for fine work on dark **goods. The** local lamps are 15 or 25-watt, all frosted type B, in small deep **bowl aluminum finished reflectors.**

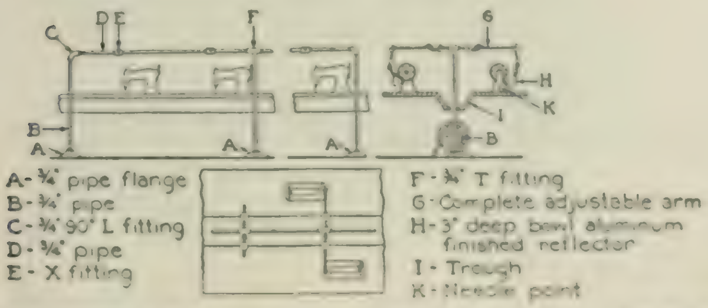


Fig. 5.—Satisfactory method of mounting adjustable arms for local illumination of sewing machines.

Fig. 6: whereas that shown in Fig. 3 is intended for work where a medium intensity is necessary. Where extremely high intensities are necessary, it is not considered economically advisable to use either of these two systems, inasmuch as the particular point where high illumination is desired is at the needle point, and if 40 ft-c. were supplied throughout the entire room, the system might not be particularly economical.. Where such is found to be the case, it is advisable to supply high intensity at the needle point by a local lamp, while a somewhat lower intensity would be supplied throughout the remainder of the room by a system of general illumination. A typical layout which will give satisfaction under these circumstances, is shown in Figs. 4 and 5. Care should be taken in choosing the type of reflector for local lighting, as indicated in Figs. 8 to 11. A night view of an excellent example of this form of lighting is given in Fig. 7. Intensities of illumination desirable for the various classes of work under this heading will be found in the accompanying tables.

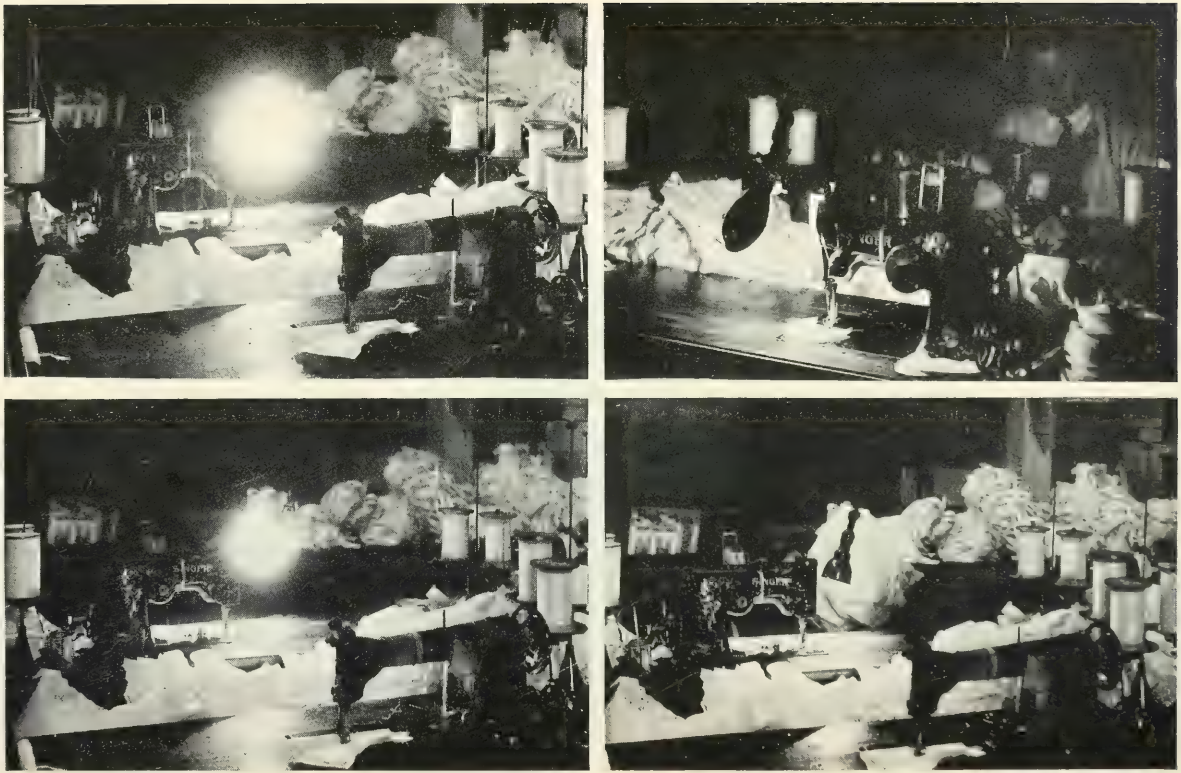
SEWING (HAND)

In every clothing factory a certain amount of hand sewing must be done. This in general is very fine work and requires good illumination. The natural posture for the operator to assume is, while seated, to take the work on her knee. Hence, it is extremely important that the lighting system be so installed as to eliminate the possibility of objectionable shadows being cast upon the work. It is also obvious that the predominating light should come from slightly in front of the position of the operator and preferably from the left. These factors no doubt had a considerable bearing on the fact that to-day a large number of factories are utilizing local lighting, that is, one unit per operator, for hand sewing.

To obtain the reduction of shadows, many factories are equipped with opal glass enclosing globes. These fixtures no doubt satisfactorily solve the problem with regard to diffusion; however, the characteristic distribution is such that economical illumination on sewing tables is not produced. Satisfactory results can be obtained by the use of localized general illumination over the sewing table, units hung from 5 to 6 ft. above the surface of the table and spaced in the neighborhood of 8 ft. apart; 100, 150

Fig. 6.—Machine sewing on sweaters with lighting as suggested in Fig. 2. [illegible]-watt bowl enameled type C lamps in standard dome reflectors are hung 6 ft. above the table in a staggered arrangement.

Fig. 7.—Night view of machine sewing with a combination of general and local lighting. 100-watt frosted type C lamps in standard dome reflectors on 16 ft. centers 10 ft. above the floor are used for general illumination. 25-watt type B lamps in a small deep bowl aluminum finished reflector provide an intensity of 30-ft-c. at the needle point. The general method of support indicated in Fig. 5 is employed.



Figs. 8—11.—Conditions to be avoided in local lighting of sewing machines. Figs. 8 and 9, half-hand shade with clear lamp showing glare in eye opposite operator. Fig. 10 a 90-deg. angle reflector almost as bad from the standpoint of glare. Fig. 11, a small deep bowl reflector, which directs the light on the needlepoint and shields the eyes of the operator.

or 200 bowl enameled gas-filled-tungsten lamps in standard dome reflectors, the size of unit, of course, depending upon the class of work. There will be good diffusion, objectionable shadows being reduced to a satisfactory minimum, and the operators will not be handicapped by having a local lamp constantly in their way.

CUTTING ROOM

The problem in the cutting room is not so complicated as that in the sewing room. Fig. 12 shows a typical layout of such a room. The tables are arranged in parallel rows, two tables back to back, thus giving a combined breadth of approximately 6 ft., while the

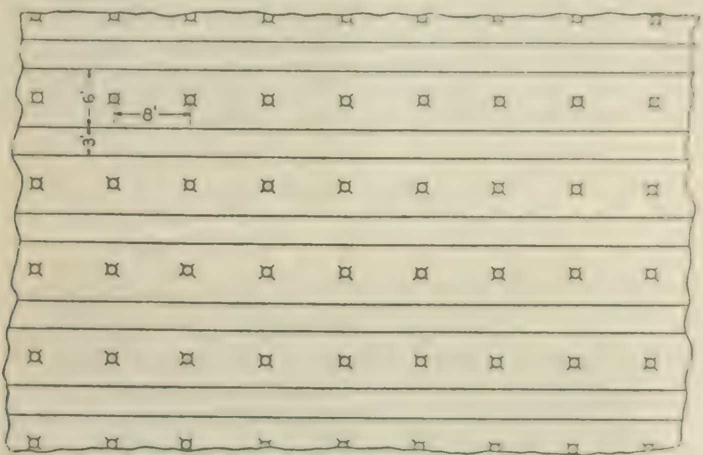


Fig. 12.—Typical arrangement of localized general illumination for cutting and hand-pressing tables. A desirable distribution of light is provided and 100, 150 or 200-watt type C lamps in standard dome reflectors permit a range of intensity for the various conditions encountered.

distance between the rows varies according to the dimensions of the floor area available. It will average, however, approximately 4.5 ft. In many factories, the nature of the work done on the cutting tables does not vary greatly. Many are used for machine cutting only, while others are used exclusively for hand cutting. In either case the cutter must carefully follow the pattern lines on the goods, and it is obvious that his ability to see easily, quickly and with confidence is of paramount importance, both from the point of view of spoilage and that of output.

Cutting machines are often equipped with an individual low wattage lamp and reflector located in front of the knife. This

method provides effective supplementary illumination if properly maintained. However, many instances have been noted where lamp and reflector have been removed entirely and in some cases a clear, bare 25 or 40-watt tungsten lamp has been inserted in the socket, defeating the purpose for which the light was originally intended.

The cutter must work along the entire length of the table in the majority of cases; hence it is necessary that a fairly even intensity of illumination be produced over the entire table surface. This is true not only for cutting, but also for the placing of patterns and marking of the goods. An arrangement of lighting units similar to that described for the hand sewing table will supply adequate illumination for this type of work, that is, localized general illumination, whereby the maximum of intensity is supplied on the cutting table itself with units being hung at a sufficient height to permit the aisles and lesser important areas being lighted to a satisfactory intensity. As is the case with the hand sewing tables, the size of the lamps selected will depend largely upon the fineness of the goods. Well-lighted cutting tables are shown in Fig 13.

KNITTING.

The type of machine, arrangement, method of drive and character and color of material must all be given due consideration in designing a lighting system for the manufacture of knit goods. If there is a fairly regular arrangement of machines and few overhanging parts, a system of general illumination will meet the requirements, otherwise, localized general illumination will undoubtedly be more practicable.

In almost all cases, diffuse illumination is desirable, not only to eliminate direct and reflected glare, but also to produce effective illumination on vertical surfaces and recesses between intricate parts of machines. There is no definite plane which demands the maximum illumination, and for this reason indirect systems or the use of diffusing enclosing globes produce the most satisfactory results. This may be accomplished by using a lighting unit which diffuses the light and gives a fairly wide spread, by hanging it quite high as compared with the spacing, and by locating outlets preferably between the machines rather than directly above.

Fig. 13.—Night view of localized general illumination of cutting boards. [illegible]-watt type C lamps in standard dome reflectors are spaced on 8.5 ft. centers 4 ft. above the tops of the tables. The average illumination is over 8 ft-c.

Fig. 14.—Looping and seaming of stockings can be carried on very effectively under lighting conditions such as shown in this night photograph. Bowl enameled 200-watt type C lamps in standard dome reflectors are hung [illegible] ft. above the floor on centers 7 x 8 ft. High level illumination of 22 ft-c. is the result.

Fig. 15.—The overhanging parts of underwear knitting machines cast dense shadows unless very diffuse illumination is provided. It is necessary to have good illumination on vertical surfaces nearly to the ceiling and the operator must glance directly upward when threading a broken strand through the eye. The installation of metal and glass semi-indirect units pictured, meets these conditions in a thoroughly satisfactory manner.

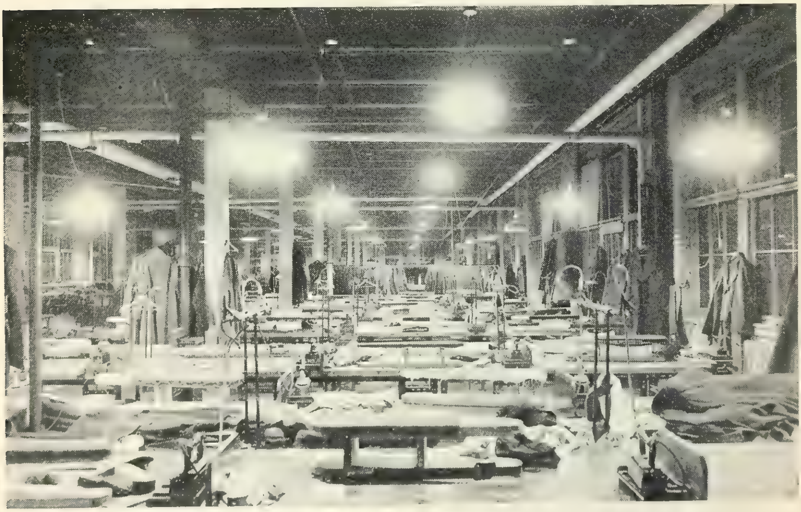


Fig. 16.—Night view of pressing department illuminated by the combination of general and localized general systems. For the former 100-watt bowl-frosted type C lamps in standard dome reflectors are placed 10 ft. above the floor, at the center of each 16-ft. bay. For the latter, 75-watt type C lamps in similar equipment are on centers 8 x 10 ft., 5 ft. above the tops of the tables.

For large knitting machines, where the parts extend quite high, the lighting must be arranged, not only to illuminate these parts to a satisfactory degree to permit inspection of the operation, but also to eliminate undue glare where the operator looks upward toward these parts. Figs. 14 and 15 picture typical conditions encountered in the knitting mill.

INSPECTION AND FOLDING.

Inspection is, perhaps, the operation which makes the most exacting demands with regard to illumination. Inspectors not only examine the work but detect stains, errors in colors, faults in the goods, etc. They are called upon to do this with reasonable speed and great accuracy. Hence, it will be seen that use should be made of a light which will bring out all of these defects in as pronounced a manner as is possible. In many factories as much of the inspection as is possible is done entirely by daylight, inasmuch as it is found that the color quality of daylight is a distinct asset in matching and detecting imperfections.

It is obvious that satisfactory artificial illumination for this class of work should simulate daylight in color value. Where extreme accuracy of color matching is important, it is clear that the most accurate type of color matching unit should be used. However in a large number of cases it is found that the daylight tungsten lamp, by supplying a quality of illumination which permits discrimination of color and discernment of imperfections in cloth, will meet the requirements.

The method of installing these units, of course, varies considerably with the class of work and the methods of the management. In underwear factories, for instance, some managers believe that it is advantageous for the inspectors to fold the garment as it is inspected, others believe strongly in the advisability of keeping an inspection department as separate from the folding department, while others believe in combining both departments, that is, placing inspectors and folders side by side—two folders to each inspector. Hence, it will be seen that for the first two methods mentioned a system of general illumination would be preferable and that it would be desirable to have this illumination of a daylight color value. In the third case, how-

ever, the tables can be arranged so as to make it possible to supply the inspectors with a local color matching unit, whereas the folders can be supplied with illumination from the ordinary incandescent lamp..

FITTING ROOM.

The requirements in the fitting room are simple and do not vary to any great extent. A medium intensity of general illumination supplied by units which properly diffuse the light will prove satisfactory in the majority of cases.

When the fitting is done on models, no thought need be given to the decorative features of the fixtures. However, the illumination should be such as to eliminate objectionable shadows on the model, and if possible the light should approximate the color value of that under which the garment is to be worn.

In cases where the fitting is done on a customer, or rather where a room is designed for that purpose, careful attention should be given to the decorative features of the fixtures. Such a condition approximates those found in a store and should be treated accordingly.

PRESSING.

Pressing is divided into two classes, that is, hand pressing and machine pressing. In the former, broad tables are employed, operators standing on each side. Each operator has a buck which stands about 9 in. from the table and is about 2 ft. long. On this most of the pressing is done. While the work is not of a particularly fine nature, a fairly high intensity of illumination is required. Since the operators face the table, a localized general system of illumination, consisting of a row of lamps hung over the center of the table 5 to 6 ft. above the table top (see Fig. 16) or a well designed system of straight general illumination will meet the requirements. In order that scorches may be more easily detected, it is recommended that the installation of daylight tungsten lamps be considered for this process. With illumination of a color value approximating daylight, the brown or yellow caused by the scorch will be more easily detected than if a light having a preponderance of yellow rays is used.

When ironing machines are used, it will often be found desirable to utilize a system of localized general illumination, on account of the liability of shadows being cast by overhanging parts. For this service the units should be hung almost directly above the head of the operator. An equipment which will meet the lighting requirements consists of the standard dome reflector and a 75-watt bowl-enameled gas-filled lamp hung about 9 ft. from the floor.

LAUNDERING.

In the laundry the construction of much of the machinery is such that objectionable shadows may be encountered, unless the lighting equipment is carefully selected and installed. With the many overhanging parts, the location of outlets is especially important. Localized general illumination is recommended for the majority of operations where average conditions exist.

As mentioned under headings of pressing and inspecting, daylight tungsten lamps are quite applicable for similar operations in the laundry as an aid in the detection of spots, stains and scorches.

STOCKROOM.

The layout for this room generally consists of rows of shelves or racks on which the finished goods are placed before being shipped. Since it is necessary to read the lables which are usually in small print or writing on the tag, a reasonably good intensity of illumination is required. A satisfactory method of illumination consists of locating rows of units down the center aisle between the racks; a reflector giving a fairly wide spread being usually desirable. Lighting units should be hung at a height so that they will come at least to the top of the shelves and preferably slightly higher. Seventy-five watt bowl-frosted or bowl enameled gas-filled lamps in standard dome reflectors or shallow dome reflectors, spaced from 10 to 15 feet centers will supply fairly adequate illumination.

SAMPLE AND SHOWROOM.

Here the problem very closely resembles that in the modern store. A fairly high intensity of well diffused general illumi-

nation will meet the requirements. Care should be exercised in the selection of fixtures in order that the proper decorative element will be obtained. The employment of either semi-direct or totally indirect lighting fixtures would be justified in this case.

Under some conditions the use of the daylight tungsten lamp will prove advantageous, this being true, of course, if the goods on display are of such a nature that it is desired to bring out the colors in the true form, or where it is desirable to discriminate between different colors. Under the most exacting conditions of color discrimination, it is recommended that the more accurate form of color matching units be employed.

PACKING AND SHIPPING.

The requirements for this class of work present no great difficulty. A system of general illumination with a reasonable intensity will suffice. Approximately 1 watt per square foot will supply adequate illumination. The type of reflector which meets the demand in the majority of cases is the standard dome. Lighting units should be so installed that there will be no great variation in intensity and a reasonable minimum of objectionable shadows.

CONCLUSION.

There are, of course, several other departments in the modern clothing establishments which have not been mentioned. However, the writers have endeavored to cover the principal ones and in so doing believe that the types of lighting suitable for all have been mentioned. The nature of the unmentioned departments' work is similar in character to one of those described, and therefore, similar lighting requirements will prevail. The proper lighting systems and desirable lighting intensities for various processes in the manufacture of clothing are set forth in the accompanying tables—

Operation	Coats and suits (Dark) Sys-tem	Coats and suits (Dark) In-tens in Ft.-C	Coats and Suits (Light) Sys-tem	Coats and Suits (Light) In-tens in Ft.-C	Corsets Sys-tem	Corsets In-tens in Ft.-C	Underwear Sys-tem	Underwear In-tens in Ft.-C	Shirts, Collars and Waists Sys-tem	Shirts, Collars and Waists In-tens in Ft.-C	Knit Goods exclusive of Underwear Sys-tem	Knit Goods exclusive of Underwear In-tens in Ft.-C	Furs Sys-tem	Furs In-tens in Ft.-C	Overalls Sys-tem	Overalls In-tens in Ft.-C	Gloves Sys-tem	Gloves In-tens in Ft.-C
Designing	L & G	L 20-25 G 12-15	L & G	L 25-30 G 8-10	L & G	L 25-30 G 8-10			L & G	L 15-20 G 2-4	G	6-8	L & G	L [illegible] G 12-15				
Machine cutting	L G	8-10	L G	6	L G	6	L G	6-8	L G	5-7					L G	4-6	L G	5-7
Hand-cutting	L G	10-12	L G	8-10	L G	8			L G	6-8			L G	10-15	L G	4-6	L G	8-10
Shading	L G†	15	L G†	15														
Machine sewing	L & G	L 35-40 G 4-6	L & G	L 25-30 G 4-6	L & G	L 25-30 G 4-6	L G	10-12	L G	8-10	L G	8-10	L & G	L [illegible] G 6-8	L G	6-8	L & G	[illegible]
Hand sewing	L G	15-20	L G	12-15	L G	10-12	L G	10-12	L G	8-10	L G	8-10	L G	15-20			L G	15-20
Other hand work	G	6-8	G	4-6	G	4-6	G	3-4	G	4-6	G	4-5					L G	5-8
Pressing, ironing	L G†	8-10	L G†	8					L G	4-6								
Examining	Color Mat'g Units	15-20	Color Mat'g Units	12-15	L G†	10-12	L G†	10-12	L G†	10-12	L G†	8-10	Color Mat'g Units	15-20	L G	6-8	Color Mat'g Units	15-20
Folding							G	4-6	G	4-6	G	4-5			L G	6-8		
Knitting							L G	6-8			L G	10-12					L G	10-12
Laundry							L G	2-4	L G	4-6	L G	5-10						
Fitting room	G	8-12	G	8-12									G	8-12	—			
Sample and show room*	G	10-12	G	8-10	G	8-10	G	8-10	G	8-10	G	8-10	G	10-12	G	8-10	G	8-10
Stock and shipping	G	2-6	G	2-6	G	2-6	G	2-6	G	2-6	G	2-6	G	2-6	G	2-6	G	2-6

Symbols
- G — System of General Illumination
- L G — Localized General System of Illumination
- L & G — Local and General Systems Combined

*Color Matching Units where Accurate Color Discrimination is Necessary.
†Daylight Lamps—Bowl Enameled or Bowl Frosted

Operation	Hats	
	System	Intensity in ft. cdls
Machine sewing	L & G	L. 15—20 G. 4—6
Hand sewing	L G	8—10
Pressing and ironing	L G	5—10
Examining	L G	10
Braiding	L G	6—8
Fur room	L G	6—8
Blowing	L G	4—6
Forming and hardening	L G	6—8
Sizing	G	5—6
Stiffening	G	5—6
Stretching and blocking	G	5—6
Finishing	L G	8—10
Sample and show room	G	10—12
Stock and shipping	G	2—6

Symbols { G :—System of general illumination
L G ;—Localized general system
L & G :—Local and general systems combined }

DISCUSSION

E. D. Tillson: To-day and on other occasions we have heard Mr. Goodwin expound in a splendid way, his plan of co-operation between the central station man, the manufacturer, the jobber, the contractor, the dealer and the consulting illuminating engineer. Each is to be active in his legitimate sphere, and shall not covet anything that is his neighbors.

But has not Mr. Oday "spilled the beans" on Mr. Goodwin, as it were? He says that there were quite a number of small sweat shops where it did not pay the contractor to fix up the lighting. I would go even further and say that in every city there are thousands of primitively lighted factory premises that do not interest the jobber, contractor, dealer or consulting engineer in the least—why?—because "there is no money in it"—they are too small. But, they should be fixed up, and the central station is very much interested in seeing it done. If no one else will do the job, the central

station must, even if it breaks every one of Mr. Goodwin's rules in the attempt.

Every disgracefully lighted factory sets a low example to hundreds of other customers of the central station, something the latter cannot ignore, and the utility is the only one I can think of off-hand that can afford to remedy the condition, since its return is not in the form of a few dollars of merchandise sold, but in added power consumption of this customer and others, that may extend many years into the future. In other words, the central station is the only one that has a permanent stake in that customer.

Another thing—good lighting is not merely a question of what is installed, and by whom—the other half of the question is maintenance, and with very few exceptions, I have never seen a manufacturer, jobber, contractor or dealer who cared a straw about how his lighting jobs were maintained, once installed—or ever went back to see whether they were maintained or not, and the owner does not care, we all know that. But, the central station does care, which is one reason why it has engineers whose business it is to study maintenance and put it into effect. The utility with which I am connected, for example, has employed a very extensive lighting maintenance division for a number of years.

Then again, there are many instances whereby using adapters, inverters, lamp-positioning devices, eye-shields, etc., an obsolete lighting job may be revamped to furnish quite a fair type of lighting. Last year at Cleveland, Messrs. Hogue, Kirk and the writer presented a paper that described many improvements of this sort. Now, you could not get a jobber, dealer or contractor to consider such an idea—too much service is involved—"there is no money in it." Of course, we might all prefer to rip out the old job of lighting and install brand new equipment throughout, but why, if it is unnecessary? And who wants one of these revamping jobs except the central station?

W. L. GOODWIN: I want to say that I have always been an advocate of the central station doing the very things that Mr. Tillson talks about. I think that the central station in every community should assume the position of the drum major in the

parade, but they should set a step and play a tune that the whole electrical industry would be glad to get in step with. In other words, if the central station realizes the need of doing work that the merchandisers in the industry are not capable of doing, that is desirable, but recognize simple business ethics, and conduct the campaign and operations on the same basis so that it will induce others to follow the practices they set, they are giving a great help.

THE PATHOLOGICAL EFFECTS OF RADIATION ON THE EYE*

BY F. H. VERHOEFF, M. D., AND LOUIS BELL, PH. D.

SYNOPSIS

The liminal exposure capable of producing photophthalmia is in terms of energy 2×10^6 erg seconds per square cm. of abiotic† radiation of the character derived, for example, from the quartz lamp or the magnetite arc. Abiotic action varies inversely as the square of the distance of the light source.

The period of latency in a general way varies inversely with the severity of the exposure, but a theoretical latency of 24 hours or more corresponds to an exposure entirely subliminal.

The combined effect of repeated exposures to abiotic radiations is equivalent to that of a continuous exposure of the same total length, provided the intermissions are not long enough to establish reparative effects. Approximately, the exposures are additive for intermissions of somewhat less than 24 hours.

Abiotic action for living tissues is confined to wave-lengths shorter than 305 $\mu\mu$.

Even with the exposures through the cornea, as great as one hundred and fifty times the liminal for photophthalmia the lens substance is affected to a depth of less than 20 μ, and this superficial effect undergoes in the rabbit complete repair.

The histological changes produced by abiotic radiation are radically different from those produced by heat, and the cell changes are best seen in flat preparations of the lens capsule.

The lens protects completely the retina of the normal eye even from the small proportion of feebly abiotic rays which can penetrate the cornea and vitreous.

*A paper presented at the Annual Convention of the Illuminating Engineering Society, Rochester, N. Y., September 26-29, 1921.

† The term "abiotic" was introduced by French observers to indicate the injurious effect of ultra-violet light on living matter.

Experiments on rabbits, monkeys and the human subject prove that the retina may be flooded for an hour or more with light of extreme intensity (not less than 50,000 lux), without any sign of permanent injury.

The retina of the aphakic eye, owing to the specific and general absorption of abiotic radiations by the cornea and the vitreous body, is adequately protected from injury from any exposures possible under the ordinary conditions of life.

To injure the cornea, iris, or lens, by the thermic effects of radiation, requires a concentration of energy obtainable only under extreme experimental conditions.

Infra-red rays have no specific action on the tissues analogous to that of abiotic rays.

Actual experiments made on the human eye show conclusively that no concentration of radiation on the retina from any artificial illuminant is sufficient to produce injury thereto under any practical conditions.

Eclipse blindness, the only thermic effect on the retina of common occurrence clinically, is due to the action of the concentrated heat on the pigment epithelium and chorioid, this heat being almost wholly due to radiations of the visible spectrum.

The abiotic energy in the solar spectrum is a meager remnant between wave-lengths 295 $\mu\mu$ and 305 $\mu\mu$, aggregating hardly a quarter of one per cent of the total. At high altitudes and in clear air it is sufficient to produce slight abiotic effects such as are noted in snow blindness and solar erythema. The amount of abiotic energy required to produce a specific effect in solar erythema is substantially the same as that required for mild photophthalmia.

Erythropsia is not in any way connected with the exposure of the eye to ultra-violet radiations, but is merely a special case of color fatigue.

Vernal catarrh and senile cataract we can find no evidence for considering as due to radiations of any kind.

Glass blowers' cataract is not due to abiotic action, but is probably due to the overheating of the eye as a whole with consequent disturbed nutrition of the lens.

Commercial illuminants we find to be entirely free of danger under the ordinary conditions of their use, even when accidentally used without their globes. The glass enclosing globes used with all practical commercial illuminants are amply sufficient to reduce any abiotic radiations very far below the danger point.

Under ordinary conditions no glasses of any kind are required as protection against abiotic radiations. For protection against abiotic action in experimentation, or in the snow fields, ordinary colored glasses are quite sufficient.

The fundamental purpose of this investigation has been to discover what if any pathological effects can be produced upon the structure of the eye by exposure to artificial or natural sources of light. That such action may occur under sufficiently powerful exposure to radiant energy is certain, but the essential fact is the discovery of the quantitative relations between the amount of incident energy and the effects. These relations have generally been left quite out of the reckoning in discussing the subject, with the result of leading to vague and often quite unwarranted conclusions as irrelevant as if one should condemn steam heating as dangerous because one can burn his finger upon a radiator.

One of us has investigated recently the energy relations of the radiation from various sources of light both natural and artificial, and the intent of the present investigation has been to determine by actual experiment on the eye the quantitative and qualitative effects of radiant energy on the conjunctiva, cornea, iris, lens and retina.

With the introduction of the electric arc, mild cases of ocular trouble due to over exposure to the arc began to attract attention, at first nearly a half a century ago, and the subject has occupied an increasing space in the literature ever since. More recently attention has been particularly drawn to the ultra violet radiation as productive of these pathological conditions, and most of the investigations bearing on the general subject have been directed toward the study of the specific action of the ultra violet. It, therefore, becomes of fundamental importance to examine the effects of radiant energy with special reference to their relation to the wave length of the radiation.

The rationale of the chemical effect of radiation seems to be that while all radiation transfers energy to the molecules which absorb it and produce heat, certain particular wave frequencies fall into step, as it were, with the oscillation periods which depend on the molecular structure, and so break up the molecules when the energy absorbed is sufficient. The particular kind of radiation which produces this direct action depends on the character of the molecules. Thus, for instance, the green modification of silver bromide is readily broken up by radiation of wave length as great as 1 μ, while it requires radiation of double this frequency to affect ordinary silver bromide, and the molecules of living protoplasm begin to break up only when the wave length is down to about 300 $\mu\mu$ as we shall show.

PHOTOPHTHALMIA

Inasmuch as most of the pathological changes in the eye observed, after exposure to light, either clinically or experimentally, have been ascribed to the action of the ultra violet part of the spectrum, it is with this that our work has chiefly been done, although we have also examined the effect of the other radiations which are received from natural or artificial sources.

Our first aim was to ascertain what quantitative relations existed between the incidence of energy on the eye and the pathological effects which might follow. Especially we desired to ascertain whether these effects were proportional to the incident energy and hence to such primary lesions as might be produced by it, or serve to set in train pathological changes of an extent not proportionate to the primary inducing cause. To this end we first turned out attention to the so-called opthalmia electrica or photophthalmia, at once the earliest known and commonest of the superficial pathological effects of radiation.

An ordinary clinical case of photophthalmia as observed after exposure to arc lights, short circuits, and the like, commonly takes the following course. After a period of latency, varying somewhat inversely with the severity of the exposure, but usually several hours, conjunctivitis sets in accompanied by erythema* of the surrounding skin of the face and eyelid. There is the sensation of foreign body irritation, more or less photophobia, lacri-

*redness.

mation, and the other ordinary symptoms of slight conjunctivitis. Occasionally there is some swelling of the conjunctiva. The symptoms usually pass off in two or three days, and in severe cases there may be scaling of the affected skin around the eye. In a very few instances the cornea has been slightly and temporarily affected. There is almost always immediately following the exposure, and quite unconnected with the photophthalmia proper, the ordinary results of a glare of light in the eyes, persistent after images, occasional scotomata, erythropsia and xanthopsia.

Our first series of experiments was concerned with the relation between cause and effect in photophthalmia of rabbits following exposure to a powerful source of ultra violet radiation. As the source of energy we employed a quartz mercury lamp operating on 220 volt circuit and normally taking 3.5 amperes with about 90 volts across the terminals of the tube. This was the same lamp of which the radiation has already been studied by one of us and which furnishes by far the best source of energy for such experiments, inasmuch as its ultra violet radiation is powerful and the light after running twenty to thirty minutes to heat up is extraordinarily steady. It is also remarkably advantageous in the distribution of energy in its spectrum, since it gives off relatively little radiation of long wave length, the nearer infra red region being particularly weak, so that results obtained by it are not complicated, save in some experiments with bacteria, by any effects due purely to temperature. Although there is considerable heat loss in the lamp it is nearly all in the form of heat waves of very long wave length which are wholly cut off by a cell containing pure water, the infra red lines of the spectrum being very few. As respects the radiation from this lamp, therefore, it is practically all in the visible and ultra violet portions of the spectrum, 35 per cent being in the visible spectrum itself and 65 per cent in the ultra violet between wave lengths 400 $\mu\mu$ and 200 $\mu\mu$. This 65 per cent is equally divided between wave lengths 400 $\mu\mu$ to 300 $\mu\mu$ and 300 $\mu\mu$ to 200 $\mu\mu$, as one of us has already shown. As the lamp was run the total radiation of energy having wave lengths less than 400 $\mu\mu$ at a distance of 50 cm. from the tube was to a very close approximation 11,000 ergs per second per square cm., of which 5,500 ergs per square

cm. of energy were of wave length less than 300 $\mu\mu$. At distances other than the standard one here noted, the radiation follows the law of inverse squares with substantial precision.

Determination of Liminal Exposure

As a starting point in our experiments it was necessary to determine, using the standard source just described, how long exposure at some known distance was necessary in order to produce clearly marked symptoms of photophthalmia. Our experimentation throughout the work has been chiefly with rabbits, since these animals have been generally used by other experimenters and the characteristics of their eyes have therefore become fairly well known.

After a few preliminary trials we found that the occurrence of slight conjunctivitis was less readily determinable than the damage to the corneal epithelium showing in the reflection of light from the cornea by a slight irregular crackled appearance giving way after stronger exposures to faint stippling. A still greater severity of exposure produces faint haziness. We also tried staining with fluorescine as index of damage to the epithelium, but found in the first stages disturbance of the corneal light reflection a more reliable guide. This indicates a somewhat more severe exposure than produces the first trace of conjunctivitis, but its presence or absence is quite definite whereas the conjunctivitis may not be easy to determine if the rabbit's eyes are naturally somewhat reddened.

The minimum exposure at 0.5 meter required to produce the first signs of pathological change on the surface of the cornea was determined to be six minutes.

Verification of Law of Inverse Squares

The outcome of this series of experiments was that radiation from the mercury vapor lamp to the amount of 4×10^6 erg-seconds per square cm. is required to set up the first definite symptoms of photophthalmia. This assumes that the effect is proportional to time, in other words, that the pathological results are determined by the total amount of energy, and the next series of experiments was directed to the establishment of the truth or falsity of this assumption. For this purpose, having ascertained the liminal exposure for a single distance, 0.5 meter, exposures

were made at various distances for times computed for equal total radiation, assuming the law of inverse squares to hold for the relative intensities. For example, at 1 meter the time required to produce the determining symptoms, assuming the law of inverse squares, should be four times that required for 0.5 meter, which was found to be closely the case. By repeated experiments at distances varying from about 20 cm. to 2.5 meters, the inverse square law was verified over a range of radiation intensities in the ultra violet varying from 72,000 ergs per square cm. per second down to 455 ergs per second per square cm., at a range in other words of 156 to 1. Since, as we shall show later, the rays which are able to injure cells by chemical action are only those of wave lengths below 305 $\mu\mu$, these present experiments of ours show that the critical amount of such radiation required to set up well marked photophthalmia is approximately 2×10^6 erg-seconds per square cm. In other words only half of the total ultra violet already specified is effective in producing such symptoms.

The Effects of Repeated Exposures to Abiotic Radiations

A natural corollory of the proposition that the pathological effects of abiotic rays on the cornea are proportional to the energy is that at least for brief intermissions the effects of repeated short exposures are equivalent to their sum in a single long exposure. This is, of course, subject to the general qualification that reparative processes are steadily going on, tending rather gradually to the healing of injured tissue. An ordinary case of photophthalmia completely disappears in less than a week and repair is going on all through this period. It is obviously possible also that apparent complete recovery may still leave the tissues slightly hypersensitive to further injury. We therefore set about investigating the effects of repeated exposures, both liminal and subliminal, to ascertain the additive effect of short exposures, the rate at which the reparative processes proceeded, the completeness of their work, and the possible effects of secondary reactions incidental to the main pathological effects.

The experiments on subliminal exposures repeated at intervals of a few minutes to an hour or more, show clearly that within 24 hours the energy effects are simply additive, intermis-

sions within this time evidently being too short for reparative action to take place. The discovery of this fact is important since it shows that with any source of abiotic rays it is the total exposure that counts, and that the effect of this total exposure, if within 24 hours, can be calculated from the data already given.

The next phase of the investigation dealt with subliminal exposures at intervals of one or more days, such as might occur in actual use of sources rich in abiotic radiation. The results show that an exposure of one-sixth the liminal repeated every 24 hours for 52 days has no visible effect on the cornea or conjunctiva. An exposure of one-third the liminal repeated every 48 hours has a slight effect on the cornea after seven to nine exposures, which however gradually disappears in spite of the exposures being continued. A daily exposure of one-third the liminal begins to produce a reaction after six exposures.

Determination of the Limit of Abiotic Action with Respect to Wave Length

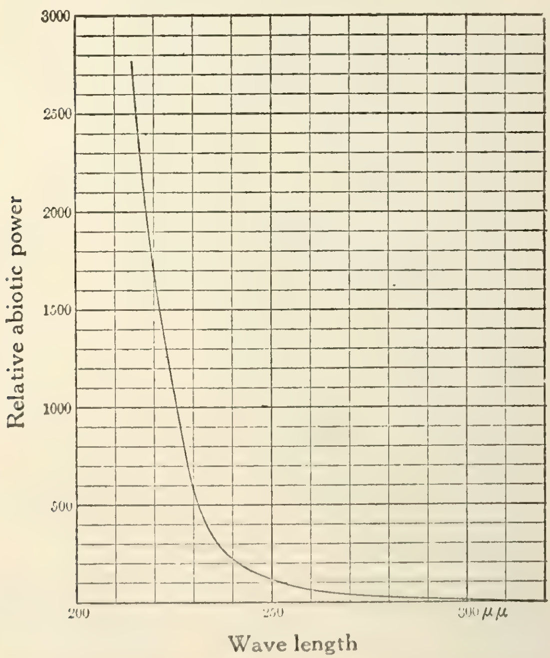


Fig. 1.—Variation of Abiotic power with wave length. (Plotted from Henri's Results.)

The critical wave length at which abiotic action on tissue cells ceases has not hitherto been accurately determined. For bacteria it has been found to be about wave length 295 $\mu\mu$. In this connection the observations of M. et Mme. Henri are important. These observers determined the coefficient of absorption of egg albumin for various wave lengths and found that the results corresponded closely with the time value of bactericidal action for the wave lengths tested. The curve of absorption plotted from their results shows that the abiotic action of light with reference to wave length may be expected to diminish rapidly and terminate at about 310 $\mu\mu$. The experiments of Widmark, Hess, and Martin, in which the lens epithelium was injured by exposures through the cornea, prove conclusively that 295 $\mu\mu$ is not the limit for human cells, since the cornea obstructs all waves less than 295 $\mu\mu$ in length. It has frenquently been assumed that there is no actual limit of abiotic action but that the latter exists in a diminishing degree through the entire spectrum. Theoretically this may be true, but practically it is not, as our experiments show, and for the following two reasons, namely, first, that in the case of the longer waves and moderate light intensities the abiotic action is so slight as to be readily overcome by the physiological activities of the cells, and second, that in the case of the longer waves and intensities theoretically sufficient to produce abiotic effects the cells are destroyed by heat action, so that there is no opportunity for abiotic effects to become manifest.

For the experimental investigation of this problem the cornea and lens are of all the tissues of the body the most suitable. This is so because, owing to their great transparency, extreme light intensities are required to produce heat effects in them sufficient to mask abiotic effects. The conjunctiva and skin are far less suitable for this purpose because when the limit of abiotic action with respect to wave length is approached the hyperemia due to heat action overshadows that due to abiotic action.

In this investigation it was necessary to abandon the use of the quartz mercury lamp employed in the earlier experiments. The spectrum of this source has conspicuous gaps in the very region to be examined for the purpose in hand. In fact there are only three rather widely separated lines in this entire debatable

region within which the limit sought was known to lie. We therefore turned to the commercial magnetite arc as the most convenient available source since this had already been found by one of us to be particularly rich in the extreme ultra violet. The spectrum is especially rich in lines between 330 $\mu\mu$ and 290 $\mu\mu$. Beyond this the intensity falls off noticeably. The source is thus particularly well adapted for work in the region here investigated. The lamp used took approximately 9 amperes at the arc which consumed approximately 750 watts. The energy in the ultra violet from wave length 390 $\mu\mu$, was about 15,000 ergs per second per square cm. at 0.5 meter standard distance ,of which approximately 3500 ergs was below 300 $\mu\mu$.

For determining the wave length at which abiotic effects on the cornea and lens cease, the use of suitable screens is very much preferable to attempts at using the spectrum formed by a quartz prism as the source of energy. This is for the reason that with screens one can obtain an enormously greater amount of energy than it is practicable to get by passing the radiation through a slit, collimating lens and prism, especially in cases where a considerable area like that of the cornea must be covered. In our experiments seven screens were employed of which the absorption was definitely ascertained by the spectrograph.

For producing intensive exposures, and particularly for work on the retina the magnetite arc here described was reenforced by the use of a quartz lens system. For one set of experiments we employed two plano convex quartz lenses each of 42 mm. diameter and 18 cm. focal length. These two were generally

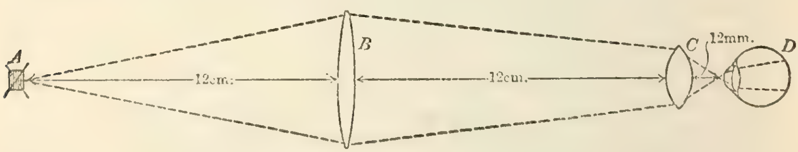


Fig. 2.—Quartz condensing system. Screens omitted for simplicity.

employed placed with the plane faces in contact either with each other or with one of our screens, making in fact a single lens of 9 cm. focal length for parallel rays. This lens was placed 20 cm. from the arc, an image of which was formed 14 cm. beyond it, at which point the eye was placed. In another set of experiments the apparatus was assembled as shown in Figure 2. The lenses

referred to, B, were placed at 12 cm. from the arc flame A. In the converging cone of rays produced by B, was placed at a distance of 12 cm. therefrom a double convex lens C of quartz cut across the axis, 23 mm. in diameter and of 14 mm. focal length for parallel rays. In the combination used, C brought the rays to a focus at about 12 mm. from its outer apex at or near which point the cornea of the eye D was located in the experiments. The path of the rays is shown by the dotted lines in the figure. The effect of the arrangement was to pass through the cornea a strongly diverging pencil producing a circle of intense light on the retina. The axial length of the ordinary rabbit's eye is about 16.5 mm. and the ordinary diameter of the area of intense illumination produced by our apparatus was about 11 mm. at the retina as was determined by actual experiment upon a freshly removed eye. With this apparatus a large amount of energy could be concentrated on any required area at or within the surface of the cornea or lens, and by aid of these lens systems we were able to obtain exposures enormously more severe than could possibly be obtained from artificial light sources in ordinary use or than have ever been obtained by previous experimenters in this field. The crucial experiments showed that for light of extreme intensity no effects either abiotic or thermic, were produced on the cornea or lens epithelium by an exposure of 1½ hours to waves over 315 $\mu\mu$ in length, and that no abiotic effects but slight thermic effects were produced by light containing wave lengths of 310 $\mu\mu$ and longer. Light containing wave lengths of 305 $\mu\mu$ and longer, produced marked thermic effects but no abiotic effects after one hour exposure, but after 1½ hours exposure produce marked thermic effects and the slightest possible trace of abiotic effects.

The insignificance of the abiotic action at wave length 305 $\mu\mu$ becomes more apparent when the equivalent critical time is computed for exposure to the direct radiations from the magnetite arc. Our experiments show that the intensity of light at the focus of the double lens system is at least eighteen times the intensity of the bare arc at a distance of 20 cm. This means that to obtain slight loss of corneal epithelium with direct waves of 305 $\mu\mu$ in length from the magnetite arc, an exposure of 27 hours

at a distance of 20 cm. or an exposure of 28 days at a distance of 1 meter would be required.

Comparing the results obtained with the quartz mercury vapor lamp and those with the magnetite arc it is found that the abiotic activity of the entire spectrum of each is in about the ratio of 6 for the mercury lamp to 5 for the magnetite arc. This ratio holds with and without the crown screen (295 $\mu\mu$).

These ratios obtained from the pathological effects are in fairly close accord with those derived from the experiments of one of us by purely radiometric methods. Taking average conditions of the two sources here referred to, the abiotic radiations from quartz lamp should aggregate about 4200 ergs per second per square cm. at the standard distance of 0.5 meter. The magnetite arc as used gave abiotic radiations aggregating about 3300 ergs per second per square cm. at the same distance. The ratio between thes two quantities is 5 to 6.35 as compared with the 5 to 6 of the pathological results, an agreement quite as close as could reasonably be expected considering the nature of the case.

The Character of the Reactions of the Ocular Tissues to Abiotic Radiations

conjunctiva and cornea

Clinical: Our experiments show that the effects on the conjunctiva and cornea of moderate exposures of waves less than 295 $\mu\mu$ in length do not differ qualitatively in their clinical aspects from those produced by longer exposures to waves from 295 $\mu\mu$ to 305 $\mu\mu$ in length. Severe exposures, however, produce markedly different effects on the cornea in the case of the short waves than in the case of the longer waves, owing to the fact that the latter are not fully absorbed by the corneal stroma.

After exposure of a rabbit's eye to light containing abiotic rays, no immediate changes take place, however great the intensity, provided a heat effect is not produced, and symptoms of irritation do not usually appear for several hours. In other words, there is a latent period before any visible effects are produced. This exists not only as regards clinical symptoms but also as regards histological changes. In a general way it varies inversely as the severity of the exposure, but in no case is

the first appearance of symptoms delayed longer than twenty-four hours. That is to say, a latency longer than this corresponds to an exposure too slight to produce any demonstrable effects. The shortest latent period observed by us was thirty minutes. This occurred after intense exposure to the short waves of the magnetite arc. The least effect that occurs after exposure to abiotic radiation consists in slight congestion of the conjunctiva. After more intense exposures the congestion is correspondingly greater and is associated with swelling and purulent discharge. There also may be conjunctival ecchymoses. The cornea, after exposures sufficient to produce slight conjunctivitis, remains clear and shows only slight stippling of the surface. After longer exposures the cornea becomes hazy in a rather sharply defined central area. This delimitation is no doubt due chiefly to the fact that the rays strike the periphery of the cornea obliquely so that there is less light here per unit area, and to a less extent to the greater loss by reflection at the periphery. Over the central area the epithelium shows marked stippling and is then cast off, usually, however, not until about 24 hours. The loss of epithelium sometimes cannot be determined without the use of fluorescine staining, owing to the margins of the defect not then being sharply defined. This is due to the fact as shown by microscopic examination, that the epithelium usually becomes thinned by desquamation before solution of continuity occurs. The haziness of the cornea usually reaches its maximum in about 48 hours, when, as will be pointed out, there is some leucocytic infiltration.

After 3 days the purulent conjunctival discharge becomes less, but it may not entirely subside for about 9 days. The corneal epithelium is usually reformed on about the 4th day. Haziness of the cornea noticeably begins to subside in 3 to 10 days. After five weeks only a slight central haze remains. Following sufficiently intense exposures, new vessels are seen extending into the cornea from the limbus in about six days.

The conjunctival reaction that occurs after moderate exposure to abiotic radiations, is only in very small part reflexly due to irritation of the cornea. This is proved by several experiments in which the cornea was exposed through a diaphragm which protected the conjunctiva. Here, although the cornea was

markedly affected, and the epithelium destroyed, the conjunctiva showed no reaction until after about 48 hours, and then only slight hyperemia.

The Iris

Clinical. Twenty-four to forty-eight hours after an exposure sufficient to injure the lens epithelium, the pupil becomes contracted and the iris shows marked congestion and minute interstitial hemorrhages in the exposed region. The congestion quickly subsides, but the hemorrhages may remain visible for several weeks.

The Character of the Changes Produced in the Lens by Abiotic Radiations

In none of our experiments was an opacity of the lens produced sufficient to be visible through the cornea. Even when the lens was examined in air after its removal from the eye it appeared perfectly clear. If, however, it was placed in normal salt solution it showed a delicate haziness in the pupillary area 48 hours after a severe exposure.

To determine the effect of the abiotic radiations upon the lens substance the lens in one experiment was fixed in formalin and horizontal sections made of it. The magnetite arc, water cell and system of quartz lenses were used without a screen, and the exposure was 20 minutes. This exposure had been found to produce extreme changes in the capsular epithelium. The eye was enucleated at the end of 48 hours. On microscope examination the lens capsule proper is found unaltered, while the epithelium shows marked changes. The lens substance is definitely affected but only for a microscopic depth, the distance beneath the capsule by actual measurement nowhere exceeding 20 μ.

POSSIBLE ABIOTIC EFFECTS OF RADIANT ENERGY ON THE RETINA

It might be supposed that if a source of light is not sufficiently rich in abiotic rays to damage the cornea, the retina could not be injured by these rays. This, however, is not necessarily true because if the source of light is so small in size that the area of its retinal image is less than that of the pupil, the intensity per unit

area as concerned transmissible rays will be greater on the retina than on the cornea. In fact under certain conditions, and with a moderately dilated pupil the intensity of the light reaching the retina will be enormously greater than the same light as it passes through the cornea. For this reason it will be seen that if the transmissible rays were capable of injuring tissue cells, the macula of the eye might be seriously damaged in spite of the fact that the cornea and lens remained unaffected. This, of course, actually happens in eclipse blindness in which, however, as will be pointed out, the effect is due entirely to heat generated in the pigment epithelium.

There are two conceivable ways, exclusive of heat effects, in which the retina could be injured by light. If the light were sufficiently intense it might over-stimulate the physiological mechanism upon which the perception of light is dependent and thus lead to more or less permanent impairment of this mechanism. It is obvious that such an effect could not readily be produced by light of wave lengths less than 400 $\mu\mu$ since the latter has relatively little power to stimulate this mechanism even in aphakic eyes. The other possibility is that intense light might injure the cells of the retina by abiotic action in the same way that light rays of short wave length injure tissue cells in general. In connection with this possibility two facts previously established by us must be taken into consideration, namely that within wide limits discontinuous exposures to abiotic rays have the same total effect as a continuous exposure of the same total length, and that there is a limit below which such summation does not occur. Thus it would *a priori* seem possible that if an individual fixed a bright source of light many times daily, serious damage to the macula might result.

The problem in regard to the retina that chiefly concerns us in the present investigation may be briefly stated thus: exclusive of a heat effect, can the retina of the human eye be injured by light of any or all wave lengths that can possibly reach it through the cornea and lens? In attempting to answer this question it is important first to inquire whether or not the waves that are able to pass through the dioptric media are injurious to tissue cells in general. If they are so injurious the question is obviously to be

answered in the affirmative. If they are not, the question is in all probability to be answered in the negative, but not perhaps with absolute certainty, since it is conceivable that the retinal cells are more susceptible to injury by light than are other tissue cells.

It has been shown by Hallauer and others that the adult human lens always absorbs all waves less than 376 $\mu\mu$ in length, and usually all those less than 400 $\mu\mu$ in length. Now we have already shown that the corneal epithelium and lens capsule are not affected in the slightest degree when exposed one and one-half hours to rays as short as 310 $\mu\mu$ even when the intensity is considerably greater than that to which the retina is ever subjected in the case of any of the known artificial light sources. This exposure is at least forty-five times greater than that required to affect the corneal epithelium by waves of 295 $\mu\mu$ and less. For the retina therefore to be affected by the abiotic action of light transmitted by the lens, it would have to be many times more sensitive to such action than the corneal epithelium. There is no reason to believe however, that this is the case, but on the contrary, since the abiotic effect depends upon the amount of absorption of the waves, there is strong reason for believing that the corneal epithelium and retina are about equally sensitive to abiotic action. Assuming this to be so, these experiments show conclusively that the human eye could be fixed steadily and at close range upon the mangetite arc certainly for over two hours and probably for many hours without suffering damage to the retina from abiotic action. Since as already pointed out the intensity of the image of a source of light of such small size as that in question decreases as the square of the distance, the danger of injury to the retina at ordinary distances would be absolutely negligible.

In the case of the lenses of some children, Hallauer found a very weak transmission band of 315 to 330 $\mu\mu$. This, however, does not invalidate the application of the above argument to the case of children, since we have shown that such waves are without abiotic effect.

While it seems to us that the foregoing facts prove conclusively enough that the lens affords complete protection to the retina from the abiotic action of light, in view of the fact that

Birch-Hirschfeld claims to have produced pathological changes in the retinae of normal rabbit's eyes by exposure to ultra violet light, we have undertaken to investigate this question by direct experiment upon the retina itself.

Such an investigation presents several difficulties. In the first place it is impossible to reproduce with animals exactly the conditions that obtain when the human eye is fixed upon a small intense source of light. This is so because it is impossible to insure in the case of an animal that the small image of the light source will always fall upon the same spot in the retina during the exposure. Moreover, even if this were possible it would be difficult if not impossible to find with certainty such a small area on microscopic examination unless the lesion produced was well marked. It is therefore necessary to illuminate a large area of the retina. This we did by means of a suitable system of quartz lenses used in connection with the magnetite arc. Intense illumination of such a large area, however, for a long period of time entails a danger of over-heating the fundus of the eye. This we successfully obviated by interposing a quartz cell 5 cm. thick filled with distilled water to absorb most of the infra red rays.

As will be seen the system of quartz lenses employed concentrated the light more intensely upon th cornea and lens than upon the retina. Advantage was therefore taken of this fact to determine at the same time the effect of exposures through various screens upon these structures, the results of which have already been given. None of the screens obstructed any waves longer than 305 $\mu\mu$ to 315 $\mu\mu$, that is, any waves that otherwise could have reached the retina through the lens. The screens also prevented excessive keratitis, which we desired to avoid since it would have prevented us from later making satisfactory tests of the lid reflex and pupillary reaction to light. If these reflexes had been abolished this fact alone would have furnished sufficient proof of the deleterious action of the radiations on the retina. As a matter of fact, except immediately after exposure a lid reflex was always obtainable.

The experiments showed, that, so far as can be determined by histological examination, the retina of the normal eye, exclusive of heat effects, is fully protected from abiotic action by the lens.

Since however, the objection may be brought forward that the retina may be injured so far as its function is concerned without showing any histological evidence of the fact, we have endeavored to exclude this possibility also. For this purpose we employed the monkey instead of the rabbit because this animal possesses a macula similar to that of man. With the lens system described it is easily possible to illuminate intensely a sufficient area of the retina to insure that the macula is always included. If under these circumstances the light has an injurious action on the retina it will be rendered evident, since the macula is injured, by marked impairment in sight and particularly by a loss or impairment of the pupillary reaction. To avoid injury to the cornea by abiotic rays and injury to the retina by heat we made use of a 1½ per cent solution of copper chloride in a quartz cell 5 cm. thick. The spectrum of this solution shows that it absorbs all waves shorter than 320 $\mu\mu$ as well as all the so-called heat waves. It thus does not obstruct any short waves that could otherwise reach the retina through the lens.

In these experiments two monkeys were employed in each of which the left eye was blind. One was an old female monkey, whose left eye had been rendered blind by an experimental operation involving injury to the optic nerve, one year previous to the first of the present experiments. The other was a young full grown male monkey, whose left eye had been rendered blind by injection of alcohol into the orbit nine months previous to the first of the experiments. Ophthalmoscopic examination showed complete optic atrophy in the left eye of each. Neither monkey could find the way about when the right eye was excluded from vision. Direct pupillary reaction to light was absent, but the consensual reaction was well marked. This made it possible to determine the presence of a pupillary reaction while the right eye was under the influence of the mydriatic, while the fact that the left eye was blind made it easy to detect any impairment of vision of the right eye. In each animal the visual acuity of the right eye was high, as shown by the ease with which it was able to catch flies and lice. The absence of binocular vision did not seem to hamper either animal in its judgment of distance except for a short time after the left eye has been made blind.

In all experiments the magnetite arc was used and the same arrangement of lenses employed as in the previous experiments with rabbits, the quartz cell, as stated, being filled with a 1½ per cent solution of copper chloride. The light was focussed on the centre of the cornea. The animal was placed in a box which allowed only the head to protrude, and the eyelids kept open by means of a small speculum. The head was forcibly held in position by the hand of the observer. For the first five minutes the animal was difficult to control, but after this no great difficulty was experienced in keeping the eye in place. No local or general anaesthetic was employed. Normal salt solution was dropped on the cornea from time to time. The pupil of the right eye was previously dilated by homatropine except in one experiment in which atropine was used.

To give some idea of the light intensity and duration of the exposures in these experiments, it may be well to state that one of us exposed his eye with undilated pupil to these conditions for fifteen seconds, and obtained an absolute scotoma which gradually disappeared within five minutes. Erythropsia persisted about three minutes and was followed by xanthopsia which lasted the remainder of the five minutes.

The results of these experiments showed that even with exposures of extreme intensity and length, but insufficient to produce heat effects, it is impossible to injure the retina by light containing any or all rays capable of reaching it through the lens. They exclude both the possibility of injuring the retina by over stimulating its perceptive mechanism, and also of injuring it by the abiotic action of light.

Most surprising was the rapidity with which the retina regained its function. Thus in all four experiments within six minutes the consensual pupillary reaction was fully reestablished. There was in both sets of experiments, however, a marked difference between the young and the old monkey in regard to the time required for the restoration of useful vision. In the case of the young monkey sufficient vision to enable him to see his way about, avoid hand movements, etc., was present in ten minutes after the exposure ended. The old monkey on the other hand was practically blind for an hour or more. In fact her visual acuity did

not seem to be fully restored until the morning following the exposure. Both animals were able to catch flies with their usual expertness after the mydriasis had disappeared.*

The results obtained in these experiments would also seem to be of some significance in regard to the question of light adaptation. They suggest that after a certain state of retinal fatigue is reached no further effect is produced, however long the exposure. In fact it would seem, in young individuals at least, that after this stage is reached the recuperative processes begin while the retina is still exposed. This aspect of the question, however, does not concern us here and further experiments would be necessary to elucidate it fully.

In addition to the experiments on the eyes of monkeys we have availed ourselves of an exceptional opportunity to make a similar experiment upon a human eye. The subject was a female patient aged 50 years affected with carcinoma of the eyelid and orbit, the growth being so extensive as to necessitate removal of the eye. The left eye itself was apparently normal, the media being clear and the fundus normal. The visual acuity was reduced to $\frac{20}{30}$ —(unimproved by lenses) for some reason not definitely determined, but probably due to some irregularity in refraction resulting from the pressure of the upper lid. The lower lid was almost completely destroyed, while the upper lid was somewhat drawn down by cicatricial tissue at the outer canthus. It was therefore necessary for the observer to hold up the eyelid by finger pressure during the experiment. The right eye was normal and had normal visual acuty. Before the experiment the pupil of the left eye was dilated with atropine, but the visual acuity remained the same. The total exposure was less than in the case of the monkeys, owing to the patient becoming somewhat fatigued, and for the same reason also the exposure was not continuous, but otherwise the conditions of the experiment were the same

The total exposure was 55 minutes, and the interval between the separate exposures was about 1½ minutes. The first three exposures were 3, 9, 12 minutes respectively, the remainder were

*Both of these monkeys were later killed, one after seven months, the other after fourteen months, and on microscopic examination the eyes that had been exposed were found normal.

5 minutes each. At the beginning of each exposure the patient stated that the "light was like the sun." At the end of the sixth exposure there was erythropsia and the visual acuity was reduced to counting of fingers at one foot. Within $2\frac{1}{2}$ minutes after the last exposure the consensual pupillary reaction was well marked, and the patient could with difficulty count fingers at six feet. Three minutes after the last exposure there was only slight erythropsia. Xanthopsia was not noted at any time but may have been unrecognized by the patient. After 10 minutes the visual acuity was $\frac{20}{200}$. There was an appearance of a mist before the eye, but no erythropsia. After $1\frac{1}{2}$ hours the visual acuity was $\frac{20}{100}$, and a slight mist still persisted. After 3 hours the visual acuity was $\frac{20}{40}$ +, and a white surface seemed almost but not quite as white as with the right eye. After 22 hours (in the morning), the visual acuity was $\frac{20}{30}$—as before the experiment. There was no erythropsia, and central color vision was perfect for red, blue and green. Twenty-four hours after the exposure the eye was enucleated. On microscopic examination the cornea, iris, lens epithelium (flat preparation), and retina were found to be normal.

The result of this experiment confirms those obtained with the monkeys. It is obvious that the retina could not have been injured by abiotic action of light, since the visual acuity was fully restored within 3 hours and remained so the following morning. The rapidity with which the erythropsia disappeared was unexpected, and indicates that duration of exposure is equally as important as its intensity in the production of persistent erythropsia.

POSSIBLE EFFECTS OF ABIOTIC RADIATIONS ON THE RETINAE OF APHAKIC EYES

Since it has been shown experimentally that abiotic waves may pass through the cornea and injure the lens epithelium, it would seem that exposure of an aphakic eye to a light source rich in such waves might seriously damage the retina.

In endeavoring to demonstrate by direct experiment the possibility of injuring the retina of the aphakic eye by abiotic radiation we have found it difficult to obtain a satisfactory eye for the

purpose. While it was easily possible to remove the lens from the rabbit's eye, the pupil became more or less completely obstructed in almost all cases. In one animal, however, we finally obtained by means of repeated discissions, a clear pupillary opening sufficient to admit the cone of light from the quartz double lens system and magnetite arc. According to our calculations and experiments an exposure of 35 minutes with the light focussed upon the pupillary area should have been sufficient to produce abiotic effects in the retina. As a matter of fact no abiotic effects could be demonstrated in the retina although marked heat effects were obtained in the pigment epithelium. This experiment thus goes to show that the danger to the retina from exposing the aphakic eye to abiotic radiations is even less than is indicated by our calculations.

Thermic Effects of Radiant Energy on the Eye

The Cornea. In passing through the cornea, light of any wave length is absorbed to some extent. Waves less than 295 $\mu\mu$ are completely absorbed while those over 315 $\mu\mu$ in length (judging by the results of our experiments) are very slightly absorbed. The absorption of the latter is no doubt due in part at least to the lamellae of the cornea and the corneal corpuscles, which cause internal reflections and refractions, especially of the relatively short waves. With ordinary light intensities the amount of energy absorbed is so slight that no heat effects are produced, but with extreme intensities it is obvious that the latter could be produced even in the case of visible rays. In five of our experiments definite heat effects were observed in the cornea. That the effects were due solely to accumulated heat and not in any degree to abiotic action, is proved by the character of the changes produced, and by the fact that the epithelial cells of the cornea and lens were unaffected. The screens were such that the lens received waves of the same wave lengths as did the cornea. The corneal epithelium was unaffected probably owing to its being cooled by contact with the air. In no instance did the heat reach sufficient intensity as to cause pain.

Combined Thermic and Abiotic Effects of Radiant Energy on the Cornea

In four experiments in which the exposures were prolonged, both abiotic and heat effects were obtained in the cornea. The screens used were transparent to waves less than 305 $\mu\mu$ to 298 $\mu\mu$ in length and the exposures were from one to one and a half hours. In two of the experiments abiotic effects were indicated by loss of corneal epithelium and characteristic changes in the lens epithelium, and heat effects by the haziness of the cornea occurring within 30 minutes after the exposure as well as by the slightness of the conjunctival reaction. Combined effects were also shown by the microscopic examinations, the corneal corpuscles being completely invisible in the posterior layers of the cornea, but present and showing characteristic abiotic effects in the anterior layers.

The abiotic effects and heat effects of radiant energy upon the tissues are essentially different. In the case of heat, a certain critical temperature is required before any effect is produced. This is shown by the sharp transition from normal into injured corneal corpuscles at the periphery of the exposed area, and also by the fact that the epithelium, being kept cool by contact with the air, remains unaffected. The heat effect therefore does not vary in direct ratio with the intensity of exposure, obviously due to the fact that dissipation of heat enters into the equation. In the case of abiotic action on the other hand the effect varies directly with the intensity of the exposure.

Thermic Effects of Radiant Energy upon the Retina

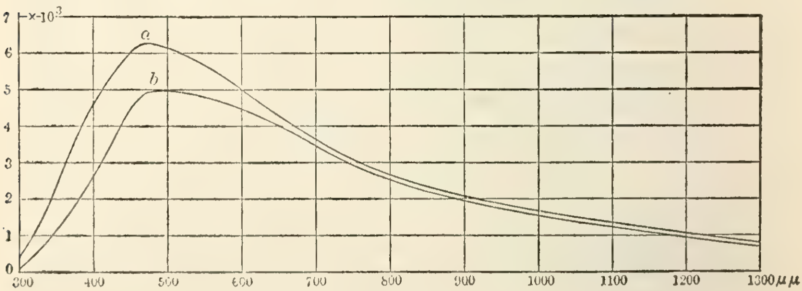
In a number of our experiments, some of which were made with other purposes in view, we obtained heat effects in the retina in spite of an interposed water cell 5 cm. thick. They were obtained mainly in two ways, one by the use of sunlight reflected from a silvered glass concave mirror 26 cm. in diameter and 1.5 meters in focal length, and the other by the use of the magnetite arc light concentrated by the single quartz lens system. In the case of sunlight the exposures were from one-fourth second to one and one-half minutes, and the resulting burns were always severe, the retinal tissue being actually coagulated. In the case of the magnetite arc the exposures were from ten minutes to one hour and the burns were much less severe.

That the severe effects produced by concentrated sunlight were due to heat was obvious from their histological appearances and from the fact that the light intensity at the focus was found in all cases to be sufficient quickly to ignite a match or piece of paper. That the relatively slight effects produced by the magnetite arc were also due to heat, was obvious from the fact that only the pigment epithelium and outer retinal layers were affected and sometimes the pigment layer alone. If the effects had been due to the abiotic action of light the inner nuclear layer and ganglion cells would necessarily have been equally or even more greatly affected.

Abiotic Energy in the Solar Spectrum

As has already been noted the solar spectrum when filtered through a thick layer of atmosphere as at sea level when the sun is low fades out at about 305 $\mu\mu$. At high altitudes and with the sun running high, it extends to about 295 $\mu\mu$. Under extremely favorable conditions some very faint traces of the spectrum were registered by Cornu down nearly to 292 $\mu\mu$.

Substantially the whole of the solar spectrum which is capable of producing abiotic action lies between 295 $\mu\mu$ and 305 $\mu\mu$, is evanescent under most conditions, and only possesses pathological significance at high altitudes and especially in extreme cold. There is good reason to believe that the atmosphere is considerably more permeable to ultra violet radiations at low temperatures than under ordinary conditions, particularly as regards the extreme radiations. Figure 3 shows from the data



a. Mt. Whitney z. d. = 0°
b. Mt. Whitney z. d. = 60°

Fig. 3.—Distribution of energy in solar spectrum.

of Abbot the distribution of energy in the solar spectrum. Two things in these curves are particularly noteworthy, first that in both and especially at the higher altitude the maximum radiation and indeed the bulk of the radiation in general lies within the visible spectrum. Second, the maximum energy lies not in the red, but in the case of the high altitude energy fairly in the blue at about wave length 470 $\mu\mu$ and at the lower altitude in the green at wave length about 500 $\mu\mu$. So far as the solar spectrum is concerned, therefore, the heat energy is chiefly within the visible spectrum. No distinction therefore can be drawn between the visible and the infra red spectrum on the ground of heat radiation and all attempts to separate thermic effects by cutting out the visible spectrum are therefore futile. So long as this reaches the eye it carries with it the solar heat in its greatest intensity. From the area of the curves here shown it appears that of the energy at high altitudes only a very small proportion, of the order of magnitude of one quarter of 1 per cent lies within the region 295 to 305 $\mu\mu$. Even this small quantity is evanescent at the sea level and at ordinary temperatures. It is to the small remaining trace of abiotic rays here noted that the phenomena of snow blindness are due. On snow fields the exposure of the eye to solar radiation, ordinarily greatly ameliorated by the obliquity of the incidence, is rendered much more severe by the reflection from the snow which is a good reflector down to the extreme ultra violet of the solar spectrum. One would not go far wrong in estimating that the radiation reaching the eye under such circumstances is of the order of magnitude of a million ergs per square cm. per second. A single square meter of snow at 2 meters distance would reflect to the eye almost a tenth of this amount with the altitude and sun favorable. Assuming now that one quarter of 1 per cent of this quantity, that is 250 ergs per square cm. per second is within the abiotic region 295 to 305 $\mu\mu$ it is easy roughly to determine the exposure which is likely to produce snow blindness. We have already seen that a well marked photophthalmia can be set up by a radiation in abiotic rays of about 2,000,000 erg seconds per square cm.

Now assuming that of the total radiation which would be received direct, half, through direct and reflected action, reaches the eye of one traveling among the high snow fields. The energy

in total abiotic radiations would be about 1250 ergs per square cm. per second. If all of this quantity had the average abiotic effect on the conjunctiva and the cornea a little less than 27 minutes exposure would be required to make up the 2,000,000 ergs seconds just referred to and to produce symptoms of photophthalmia. As a matter of fact the region from 305 $\mu\mu$ to 295 $\mu\mu$ has much less than the average abiotic effect. Our crown glass screen No. 7 cut off the ultraviolet at 295 $\mu\mu$ substantially just at the end of the solar spectrum. Experiments made with this screen on the magnetite arc which is fairly strong from 295 $\mu\mu$ to 305 $\mu\mu$ showed that this screen increased the exposure necessary to produce photophthalmia eighteen times. It therefore appears that at a high altitude in the snow fields an exposure of 7 to 9 hours under extreme conditions would be required to produce photophthalmia as severe as that which we have here recorded as typical, that is, involving stippling of the corneal epithelium. Clinically snow blindness very rarely reaches this phase, since, although the exposures may be long the intensity of abiotic solar radiations reaching the eye would be seldom as great as the maximum amount just mentioned. At sea level and under ordinary circumstances the critical exposure for snow blindness would undoubtedly run to many hours.

Solar Erythema

These data on solar energy at once call up the question of solar erythema generally attributed to the effect of ultra violet radiation. Clinically this bears a suggestive resemblance to photophthalmia in that it has a period of latency and a similar period of duration. Further it is well known to occur easily at high altitudes with the sun running high, that is under circumstances which afford a fair amount of abiotic rays. The best recent investigation of this matter is that by Dr. de Laroquette, Surgeon Major of the Franch Army in Algiers. His experiments under the intense tropical sun show the connection of solar erythema with the abiotic rays very clearly. In the first place in most cases he noted a primary erythema clearly due to temperature and perhaps associated with heated air as well as radiation, occurring only when the temperature is 30 degrees C. or more. This is followed after a period of latency of an hour or two by

a secondary photochemical erythema going on under severe exposures to hemorrhagic pigmentation, local oedema and subsequent desquamation.

Our experiments with the bare magnetite arc as source indicate that the liminal exposure for perceptible abiotic effects is practically the same for the more sensitive parts of the skin as for the conjunctiva. The inner portion of the forearm was the portion of the body exposed in our work on liminal exposures. Here with 6 minutes at 0.5 meter, which corresponds very well with the production of mild photophthalmia, a slight reddening of the skin appeared some few hours after exposure, rose to its maximum inside of the first 24 hours and vanished within a day or two leaving no trace. We found, as did Dr. deLaroquette, that vaseline acted as a fairly complete preventive as regards both primary and secondary erythema, particularly the latter, while glycerine gave a slight protective action in our results, more than would seem to be warranted in view merely of its transparency to abiotic rays. From these observations and from the clinical facts, often showing erythema greatly disproportionate to the intensity of abiotic radiation likely to be present, it seems probable that ordinary sunburn is due to a mixture of thermic and abiotic effects of which the former are often the more prominent, although they generally cannot readily be separated from the secondary abiotic effects, the development of which they tend to mask.

Erythropsia

So-called erythropsia is the name of a phenomenon rather than of a pathological condition. The clinical records are numerous but vague. They all indicate a condition, generally very temporary, in which the patient finds a more or less ruddy tinge in everything seen. There is nothing definite in the tint of the coloration or the period through which it is observable. It apparently runs from various shades of orange and rose to a fairly full red. A cursory view of the clinical records indicates that the cases cited fall into three general divisions. First, cases associated with neurosis such as those given by Charcot and others. These clearly cannot be associated with any pathological condition of the visual apparatus. Second, there are many recorded instances of traumatic erythropsia some of which at least

evidently are associated with the actual infiltration of the eye media with blood. Third, one finds a vast majority of instances which one may term photo-erythropsia in which the observed appearances, one can hardly dignify them by the name of symptoms, are associated with over exposure to light. These are so entirely without pathological significance that we should hardly consider them here save for the fact that the phenomena have been attributed to the effect of ultra violet radiations. That the ultra violet really has nothing to do with the matter is clearly shown by Vogt who found that erythropsia could not be produced experimentally by the ultra violet alone, but very easily by light ray containing no ultra violet. We need only add here that it is possible to produce marked erythropsia through euphos glass which transmits no ultra violet, through B-naphthol-disulphonic acid which also cuts off the ultra violet, and through dense flint glasses which eliminate all of the ultra violet which could with any certainty get through the lens. Also it is produced with great facility by radiation through green and blue green media which intercept the ultra violet completely, but flood the eye with light of a color certain to produce a strong red phase in the after image. The truth seems to be that the so-called photoerythropsia is merely the result of such unequal fatigue of the primary color sensations as leaves for a greater or less time thereafter a color sensation predominantly red.

Vernal Catarrh

Spring catarrah is an uncommon disease of the conjunctiva that most often affects the upper lid, much less often the bulbar conjunctiva around the corneal limbus, and almost never the two together. It is extremely chronic, lasting from 3 to 20 years, and is associated with the formation of peculiar granulation tissue, infiltrated with eosinophilic leucocytes to an unusual degree, containing downgrowths of epithelium from the surface. In the case of the conjunctiva of the lid, the new tissue forms within the papillae, thus giving rise to large flat papillary growths. The symptoms of irritation, photophobia, lacrimation, and itching, are most marked in the spring and warm seasons of the year, usually disappearing during the winter months. For this reason sunlight has been suggested as the etilogical factor in the disease.

The evidence for the view that vernal catarrh is due to the action of sunlight, amounts to little more than the fact that the symptoms are most pronounced in the spring and summer. This fact, however, is accounted for even better on the more recent theory that the disease is due to pollen. Moreover the following objections, that to us seem insurmountable, may be urged against sunlight as a cause. In the first place if vernal catarrh is due to sunlight the lower lid, which is not only more exposed, but thinner and more transparent, should be more affected than the upper lid, whereas, as a matter of fact, it entirely escapes involvement.

Finally, the possibility of abiotic action is ruled out by the fact that it is impossible for abiotic waves to pass through the entire thickness of the lid.

Senile Cataract

The theory has been advanced that senile cataract is due to exposure of the lens to daylight, particularly that from the sky. This is based solely on the fact that the cataractous changes usually begin in the lower part of the lens. It is undoubtedly true that the changes do usually first appear below, but as a rule they are so far below that they are in a portion of the lens completely shaded by the iris. Thus it is most often necessary to produce artificial mydriasis before incipient lens changes can be seen with the ophthalmoscope. Moreover, if the cataract were due to exposure to light, the pupillary area should be the first affected, since from such an extended source as the sky it receives the greatest concentration of light, and since the chief absorption must occur here. We must conclude, therefore, that there is no sound evidence for this theory of cataract formation.

Burge has recently attempted to supply an experimental basis for the view that ultra violet light is responsible for cataract. He found that the rays from an unscreened quartz mercury vapor lamp had almost no coagulating effect upon the lens protein even after an exposure of 72 hours at a distance of 5 cm but that when acting in the presence of weak solutions of calcium chloride, sodium silicate, or dextrose, coagulation occurred. Since in senile catracts calcium, magnesium, and sometimes silicates, are greatly increased, and in diabetic cataracts dextrose is presumably present, Burge assumes that these cataracts are due to the action of ultra violet light.

This assumption is sufficiently controverted by the fact just mentioned that senile cataract usually begins at the periphery where the lens is shaded by the iris, and sometimes begins in the upper part of the lens. But in addition, other serious objections to his argument may be pointed out. In the first place, in traumatic cataracts and cataracts due to inflammatory conditions, calcium salts, and no doubt magnesium and other salts, are deposited in great abundance, and the lens may even become completely calcified. In fact, the same thing occurs in dead tissues anywhere in the body, so that the reasonable assumption is that the presence of these salts in senile cataract is a result not a cause. Then, too, Burge made use of intensities of exposure and wave lengths to which the lens is never subjected during life. The cornea completely screens it from practically all the short waves found effective by him. The longest waves with which he could coagulate proteins were 302 $\mu\mu$ in length and the effect produced by these was insignificant.

The fatal objection to Burge's theory as applied to senile cataract is that the ultra violet solar rays cannot reach that portion of the lens where cataract generally begins, and that portion of the lens where ultraviolet light has the best chance of action is affected only at a late stage of development.

Eclipse Blindness and Allied Phenomena

Every recent eclipse of the sun has given rise to numerous cases of so-called eclipse blindness, due to careless observation of the phenomenon in its partial stages, either with the naked eye or with altogether insufficient protection. We should not here consider the matter worthy of attention were it not for the fact that it has been loosely ascribed, like many other imperfectly investigated ocular injuries, to the malign effects of ultra violet light. Eclipse blindness appears in literature as far back as Plato's Phaedo, and is repeatedly mentioned through classical and post classical times as an apparently not unexpected phenomenon. The eclipse of April 17, 1912, in Germany produced a total of many hundred cases of more or less injury to the eye. Every eye clinic received its toll of more or less severe cases. Clinically the immediate effect is marked and immediate scotoma, which does not pass away promptly but leaves more or less serious

cloudiness of vision and accompanying loss of acuity which may be temporary, lasting a few weeks, or in severe cases permanent. The scotoma is commonly central and generally of small extent, in a marked proportion of the cases corresponding fairly well with the dimensions of the sun's image, although wide variations from this may be due to repeated fixations overlapping or reenforcing each other. As it is generally impossible to tell just how long or how often the patient fixed the phenomenon nothing definite can be postulated concerning various varieties of scotoma which have been noted by various observers. The ophthalmoscopic observations usually show changes ranging from scarcely perceptible, to conspicuous and permanent pathological appearances involving lasting and destructive injury to the retina.

Our experiments have been directed to the production of an artificial eclipse blindness in animals, and the examination of the lesions produced, with special reference to the intensity required to produce the lesions noted. The apparatus employed was powerful enough to produce prompt and acute effects. For most of the experiment we employed the mirror apparatus.

The concentration of energy obtained by this instrument was enormously great, owing to the size of the mirror and its relatively short focal length. Its area was about 530 square cm. so that with an average reflective coefficient of 0.75, with good sunlight the reflected energy would amount to some 4×10^8 ergs per second. The energy at the focus amounts to approximately 30 watts per square cm. A pupil expanded to say 10 mm. by the use of mydriatics would therefore take in a pencil equivalent to about 24×10^7 ergs per second. Allowing as in other cases one-third for the energy absorbed by the media of the eye as a whole, the energy incident in the image would be approximately 16×10^7 ergs per second. The diameter of the image in this case is just over 2.5 mm., corresponding quite exactly to an area of 5 square mm. The energy density in the retinal image therefore would be about 32×10^8 ergs per second per square cm. and it was found in our experiments that an exposure of ¼ second to this intensity was sufficient to produce a destructive thermic effect in the retina. This short period is very striking in comparison with the relatively long exposures necessary to produce typical eclipse blindness with the naked eye, although it agrees

very well with the data which we later cite regarding energy burns from other sources. The secret of the relative resisting power of the naked eye is that usually in observations of the sun, the pupil is in extreme miosis, so that the amount of energy received is probably not more than 6 per cent of that computed for the normal pupil, while the extremely small area of the solar image favors rapid dissipation of the energy not found when a considerable area is attacked, as in the case of the mirror experiments. A priori the climical evidence is strongly against any definite pathological effects due to the ultra violet radiation as such. Numerous cases are recorded in which typical eclipse blindness has been produced through ordinary spectacle lenses, through glass insufficiently dark and through opera glasses and the like, in all of which cases the abiotic rays are, as we have already shown, cut off. Even very small thicknesses of colored or even clear glasses are sufficient completely to absorb these rays, which moreover are always cut off by the lens so that they cannot reach the retina where the lesions are found. Attempts have been made by several investigators, notably Birch-Hirshfeld, to eliminate the infra red rays also by the use of thick water cells and other absorbing media, but these attempts so far as experiments with solar light are concerned are futile, because, as a glance at Figure will show, the greater portion of the solar energy lies entirely within the visible spectrum with its intense maximum in the blue or green according to the effect of the atmospheric absorption, so that for solar radiation it is the light rays which are thermally effective, the energy radiation in the ultra violet and infra red being relatively insignificant. Our experiments show with the utmost distinctness that the effects known as eclipse blindness are wholly thermic, due to the intense concentration of the solar energy upon the retina by the refracting system of the eye itself forming an image of destructive energy intensity.

Thermic Effects on the Retina from short Circuits

It is worth noting in connection with eclipse blindness that sources of intense energy other than the sun may produce similar results. For example, Uhthoff reports the case of a patient exposed to a violent short circuit in which a fortnight after the accident grayish spots due to alterations in the pigment epithelium were observable in the macula of the left eye and were still

observable six months later. This ophthalmoscopic appearance is closely similar to that many times recorded in eclipse blindness. Still later Knapp records a case of bilateral injury produced by a tremendously powerful short circuit occurring a scant half meter from the patient's face. There was complete temporary scotoma followed on the next day by some superficial symptoms indicating photophthalmia, and a week later by metamorphopsia, while the vision had been steadily sub-normal. In each fundus was a patch corresponding to the image of the short circuit flare, in which serious damage had been done. These injured areas were still obvious a year later. The retinal lesions described, and especially the metamorphopsia, are such as are typical in the case of eclipse blindness. Here the energy radiation of the short circuit was concentrated in the image to an extent sufficient to produce a typical thermic lesion. The slightness of the abiotic radiation received is evidenced by the very brief superficial symptoms, and the retinal injury, owing to the absorption of practically the whole ultra violet by the media of the eye, must have been due essentially to the pure energy radiation of which the amount, judging by the description, was probably not less than 100 to 200 kw. A short circuit involving 100 kw. would give a superficial intensity at a half a meter of over 30,000,000 ergs per square cm., that is, more than thirty times the intensity of solar radiation. The area of the scotoma produced was, from the description, in the neighborhood of 1 sq. mm. Assuming a pupillary diameter of 5 mm. likely to be found in working in a moderate degree of light when surprised by the short circuit, the energy entering the pupil would be at least 6 by 10^6 ergs per second concentrated in the image, that is an energy density amounting to in the neighborhood of 6 by 10^8 ergs per second per square centimeter reckoned without regard for absorption. Allowing one third of the energy absorbed in the eye the energy density in the image should be 4 by 10^8 ergs per second per square cm. two or three times, at least, greater than the corresponding energy density for a direct observation of the sun, very possibly, owing to the intensity of the short circuit, even several times greater than this. It is little wonder then that although the exposure time is stated to be less than 1 second the results were serious.

THERMIC EFFECTS ON THE RETINA FROM LIGHTNING FLASHES

A consideration of these miscellaneous energy effects on the eye would be incomplete without referring to the injuries to the eye received from lightning. In such cases a sharp distinction must be drawn between cases in which the patient is actually struck by lightning, with more or less serious effects, and those in which the patient is clearly not struck, but subject to direct radiation from a nearby flash of lightning. In the second class of cases the effects are usually limited to severe scotomata which may impair vision for some hours or days but as a rule there are no lesions visible either superficially or with the ophthalmoscope, and no permanent damage is done.

There are few instances, however, in which the energy received at the eye has been great enough to produce typical lesions both from abiotic action and probably also from purely thermal effects. The case reported by Le Roux et Renaud was a specially notable one in which the patient, on guard duty at night, was exposed to a very powerful flash. It was immediately followed by violent erythropsia which lasted for some two hours. The Gendarme remained at his post and went home and to bed about three hours later. The next morning he woke with acute headache, with substantial blindness in the left eye followed a few hours later by loss of sight in the right eye. There was double acute conjunctivitis with swelling and reddening of the lids and conjunctiva and marked chemosis. A little latter there was diffuse interstitial keratitis, a change in color of the iris from blue to greenish and a grayish haze on the lens front visible in a bright light. These affections of the anterior eye cleared later and when the ophthalmoscope could be used there was marked haze in the vitreous, which cleared very slowly and not completely even after three years. This was believed by Le Roux et Renaud to be associated with chorio retinitis and was certainly secondary to the original lesions.

It is very difficult to make anything like an exact computation of the energy which produced these results, since not only is the total amount of energy in a lightning flash extremely variable and known only to a rough approximation, but the duration of the flash is also variable and uncertain. Thus much is clear, however, that the very heavy discharges, in which the length of flash

is some hundreds or thousands of meters and the quantity of electricity discharged very large, are also the relatively slow flashes since the equivalent condenser capacity is very large. The estimates of frequency rising to millions per second can have no place here, since obviously the velocity of free waves being only 300,000 km. per second, a flash of one or several km. in length cannot have a very high oscillation frequency even supposing it permits oscillations at all. Attempts to measure the frequency of the discharge have often led to results of less than .001 of a second and it is altogether probable that in these long flashes there is no oscillation at all on account of the resistance effects. Starting from the estimate of Sir Oliver Lodge of 10^{20} ergs per second and assuming an effective time of discharge .0001 of a second, and that of the total flash not over .1 is within the effective range of reaching the eye, the energy in the discharge may be reckoned as one or perhaps several thousand times that of the short circuit discussed in connection with Knapp's case. With a nearby discharge occurring say within 10 or 20 meters, the quantity of energy received by the eye would be amply great to account for even severer results than those noted by Knapp.

Glassblowers' Cataract

The fact that glassblowers are subject to a special form of cataract has naturally raised the question whether or not the latter is due to radiant energy and if so, whether to abiotic or thermic action. The cataract almost always appears first in the left eye which is the more exposed to the light. When it appears first in the right eye it has been found that the glassblower has been in the habit of turning this eye toward the oven. The glassblowers are thin and delicate, and are subject to asthma and pulmonary tuberculosis. Almost all of them have emphysema of the parotid gland. During their working hours they perspire excessively and in consequence drink enormous quantities of fluids, including beer, coffee, wine, and lemonade.

The cataract begins as a rosette like or diffuse opacity in the cortex at the posterior pole of the lens, the remainder of the lens for a long time remaining clear. Later, striae similar to those of senile cataract may appear.

The great frequency with which glassblowers' cataract occurs, its relatively uniform type, and the fact above all, that it occurs first in the more exposed eye, show clearly enough that it is chiefly due to the action of radiant energy on the eye itself. This is supported also by the fact that the cheek shows a more marked area of discoloration on the side of the first effected eye. The further questions whether the cataract is due to the direct action of the light upon the lens, or upon the eye as a whole, and whether it is due to abiotic or thermic action, are not quite so easily answered.

The character of the radiation from molten glass is well known. It is that from a homogeneous body of relatively low temperature, 1200° to 1400° C. It is certain that the spectrum of a non gaseous body at this temperature does not include any of the so-called abiotic radiation since the extreme limit of the spectrum of molten glass found by any investigator is 320 $\mu\mu$ and estimates range from that to 334 $\mu\mu$. We have already shown that the abiotic action cannot be traced beyond 305 $\mu\mu$ and there is not the slightest indication from our researches or any predecessors that there is reason to suspect an extension of such activity to waves longer than 320 $\mu\mu$. Even if there were, such rays would be stopped at the front of the lens by its absorption and hence would be unable to affect the posterior cortex. Of the rays absorbed by the lens, reaching from 300 $\mu\mu$ to about 400 $\mu\mu$, the chief absorption is, following the general theory which we have already explained, at the front surface, hence if by any stretch of imagination glassblowers' cataract could be assumed to be due to an indefinitely long application of such rays it should occur at the anterior and not at the posterior cortex. To rays in the ordinary visible spectrum the lens is notoriously transparent and in default of absorption of energy there is no reason to expect any specific effects from it. We have been able by the use of sources of extreme power greatly concentrated, as our experiments show, to obtain specific action of the ultra violet rays only to a microscopic depth, 20 μ, so that the experimental evidence lies squarely against any lesions directly producible by such sources in the posterior cortex, particularly in the absence of any effects in the anterior cortex. We are inclined to attach more importance to the view that the effect is a secondary one due to the loss of water in the

drain produced by the heat on the front of the eye and elsewhere, and especially that malnutrition due to interference with the functions of the ciliary body by the heat may be chargeable with the malady. We are the more inclined to this opinion since the intense radiation acts through the sclera as well as through the cornea, thus affecting the whole structure.

Applications to Commercial Illuminants

In considering any possible delecterious effects of radiation upon the eye there are certain pathological effects which can be at once eliminated, at least from any consideration of commercial illuminants. First, by the experiments which have been heretofore described we have made it clear that there can be no injury done to the retina by ultra violet light as such, even the most severe exposures failing completely to produce any effect whatever. Second, all thermic effects of energy from any source on the external eye are at once ruled out of consideration by the immediate discomfort produced by excessive heat. No person would tolerate extreme heat radiation on the external eye for a period long enough to produce the slightest damage. There remain therefore to be considered thermic effects within the eye, and specially those due to the focussing of intense radiation upon the retina as in eclipse blindness; over stimulation of the physiological processes in the retina, that is pathological effects due to light as such in its action on the retinal structure, and finally those abiotic effects of the extreme ultra violet rays on the external eye properly known as photophthalmia. It has been our purpose to ascertain the practical risks incurred in the use of artificial illuminants and the precautions required to avoid danger. To this end have we sought especially the quantitative relations in the action of radiant energy upon the eye. We have, therefore, experimented with the most powerful sources used for practical lighting under conditions of intensity immensely greater than occur in their every day use. We have shown that as regards the general thermic effects of energy upon the eye there is no chance of damage to the retina or to the media of the eye under any practical conditions of use. With respect to damage to the retina in particular we have been unable to produce it except by exposures and intensities enormously greater than could possibly be reached in the use of artificial sources of light. We have used

beside the quartz mercury arc which is not particularly strong in general radiation, a 750 watt magnetite arc which takes the greatest amount of energy of any arc light ordinarily used for illuminating purposes and the 750 watt nitrogen lamp which gives more ultra violet than any other incandescent source, and which failed completely to produce any specific damage to the eye, although in one experiment the animal was overcome by the general heat effect, as in sunstroke. This occurred after an exposure of 1½ hours at 20 cm. from the filament. A second experiment with an exposure of 2 hours at the same distance, in which the animal was well protected from the heat and the head kept cooled with water, showed no damage to the eye of any kind. This source as a whole focusses less sharply than does the arc lamp taking an equal amount of energy, and in this case we have already shown that the retina would not be subject to damage save by an impossibly long exposure with accurate fixation. These experiments were at far shorter distances and consequently of enormously greater intensities than any which could be found with such sources as illuminants, and we may hence conclude that so far as general effects of thermic energy are concerned no source used for illuminating purposes is capable under working conditions of producing any observable delecterious results.

Experiments with the arc lamp are crucial because this source is nearer to being a point source than any illuminant of similar power and hence gives much sharper concentration of energy in the image. It is with this concentration in the image that the possible damage to the retina is concerned. Diffuse sources which do not come to a definite focus may be entirely neglected for this particular purpose. Low temperature sources of which most of the energy lies in the extreme infra red are even less effective in concentrating energy upon the retina, because the eye never focusses such wave lengths on the retina except as a diffuse spot.

The only sources from which there seems to be any material danger from the standpoint of thermic effects are certain very powerful high temperature sources used in the arts, such as heavy arcs used for welding purposes, furnaces, electric or other, where there is customarily great concentration of energy, and such purely accidental phenomena as short circuits. Perhaps some of

the very powerful arcs used in searchlights might be included in this class of the possibly dangerous. Ordinary discretion in avoiding disagreeably powerful lights or suitably shading the eyes from them should avert easily all real danger from any of these sources of radiation, save the short circuits which are accidental rather than ordinary risks. Certainly no sources used for lighting purposes can be classified as dangerous from the standpoint of thermic effects.

We wish particularly to emphasize the fact that so far as any possible temporary or permanent injury to the retina is concerned such action must depend on the concentration of energy in the image. Consequently, extended sources of moderate intrinsic brilliancy are to be preferred to intense sources. Hence it is desirable to protect all sources naturally of high intrinsic brilliancy by diffusing globes.

As regards dangers of injury to the eye from light radiation as such, our experiments indicate that it has been very greatly exaggerated as regards its pathological possibilities. It is undoubtedly true that brilliant sources of light are disagreeable and that they produce unpleasant effects in temporary scotomata, disturbance of color vision, persistent and annoying after images and fatigue due to efforts to overcome the difficulties of vision under these disadvantages. As regards definite pathological effects or permanent impairment of vision from exposure to the luminous rays alone we have been unable to find either clinically or experimentally anything of a positive nature. As for the ultra violet part of the spectrum to which exaggerated importance has been attached by many recent writers, the situation is much the same as with respect to the rest of the spectrum, that is, while under conceivable or realizable conditions of over exposure injury may be done to the external eye yet under all practical conditions found in actual use of artificial sources of light for illumination the ultra violet part of the spectrum may be left out as a possible source of injury. All illuminants possess an easily measurable amount of ultra violet radiation ranging, as one of us has already shown from about 4 ergs per second per square cm. per foot candle of illumination in the quartz arc with the usual globe, to more than twenty times this amount in the enclosed carbon arc shining through a quartz window. Between these two lie the

whole range of incandescent lamps both gas and electric, the ordinary mercury arcs and the ordinary Cooper Hewitt tube, flames, arc lamps of various sorts, and sunlight. The last mentioned occupies an intermediate position between the high efficiency electric incandescent lamps and the older incandescent lamps or ordinary flames.

No injurious effects have been attached with any reasonable degree of certainty to the ultra violet radiation which lies between the end of the visible spectrum and the begining of the abiotic rays. Since this range of radiation is present in considerable amount in ordinary sunlight, it is sufficiently obvious that any definitely harmful results producible under ordinary conditions would have been eliminated by the ordinary progress of evolution. Artificial illuminants under any practical conditions of use expose the eye to much less severe radiation in this part of the spectrum than does ordinary daylight and *a fortiori* can be excluded as possible sources of harm.

With respect to abiotic radiations we have every reason to acquit on sound experimental basis every known artificial illuminant when working under ordinary conditions of commercial use. The only sources used in the arts which have abiotic power enough to require special caution in their use are those not employed for the purpose of illumination.

Our general conclusion, therefore, regarding the effect of radiation from practical illuminants on the hunman eye is that no sources commercially employed for such a purpose are to be regarded as dangerous and that the most ordinary care in providing illumination with which comfortable vision can be obtained is sufficient for complete security against all possibility of injury from radiation.

DISCUSSION

DR. G. S. CRAMPTON: Mr. Millar was quite right when he said that this paper may be considered a classic. For years observers have been studying the effects of ultra-violet light upon the eye and each, generally, had his own particular protecting glass to extol or defend. There was much discussion as to the necessity for protection and of the virtues of the various glasses. The question seems to have been largely settled by the advent of

the Verhoeff-Bell monograph on the subject a few years ago, a really epoch making piece of work. We know Dr. Verhoeff as probably the foremost eye pathologist in this country and his co-worker is equally well known in his field. As a result of their studies the effects of ultra-violet light on the eye are no longer dreaded by those who are acquainted with the facts but there is still much ignorance to be combated, and what makes progress still harder there appears to be a definite propaganda in this country on the part of certain makers of a protective glass having a high sounding name, to impress the public with the dangerous effects of ultra-violet light upon the eye. Undoubtedly these glasses have much virtue, under certain circumstances especially when used to prevent glare and in certain industries, but to fear the ultra-violet light that results from our modern illuminants, for its supposed effects upon the eye is a mistake.

I am glad that the authors have told us of the continuance of their work and have brought it before the public in a way which I hope will have the widest publicity.

I recall visiting the factory of the Cooper-Hewitt Company where I was told that the employees took practically no precautions to protect their eyes except possibly by wearing an ordinary pair of glasses.

Unquestionably a certain degree of immunity results from the constant exposure to the bright lights. For the first couple of weeks some of the girls who face the lights all day at short range are somewhat effected and there may be some epiphora but they soon become used to the work and continue at it without harm for years. Under these circumstances great care should be exercised that the employee is not undergoing eyestrain as a result of a faulty refraction or an uncorrected astigmatism.

J. B. Taylor: I notice in speaking of the Angstrom units in the paper Dr. Bell has used millimicrons. For myself I prefer the decimal with the single μ after it. Is the millimicron something that the Doctors understand and prefer to use?

Louis Bell: Really that is correct. I was brought up on the Angstrom, but the millimicron came in later and I have consistently tried to use it.

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Cassidy Co., Inc., Long Island City, N. Y.
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Commonwealth Edison Co., Chicago, Ill.
Consolidated Gas, Electric Light & Power Co., Baltimore, Md.
Consolidated Gas Co. of New York, New York, N. Y.
Consumers Power Co., New York, N. Y.
Cooper-Hewitt Electric Co., Hoboken, N. J.
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Dawes Brothers, Chicago, Ill.
Thomas Day Co., San Francisco, Cal.
Detroit Edison Co., Detroit, Mich.
Duplex Lighting Works of General Electric Co., New York, N. Y
Duquesne Light Co., Pittsburgh, Pa.
East Side Metal Spinning & Stamping Co., New York, N. Y.
Edison Electric Illuminating Co. of Boston, Boston, Mass.
Edison Lamp Works of General Electric Co., Harrison, N. J.
Electric Outlet Co., Inc., New York, N. Y.
Electrical Testing Laboratories, New York, N. Y.
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Gillinder Brothers, Port Jervis, N. Y.
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Gleason-Tiebout Glass Co., Brooklyn, N. Y.
Haverhill Electric Co., Haverhill, Mass.
Holophane Glass Co., Inc., New York, N. Y.
The Horn & Brannen Mfg. Co., Inc., Philadelphia, Pa.
Hydro-Electric Power Commission of Ontario, Toronto, Canada.
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Kristiania Elektrecitetsvork, Kristiania, Norway.

SUSTAINING MEMBERS.—(*Continued.*)

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Leeds & Northrup Co., Philadelphia, Pa.
Lightolier Co., New York, N. Y.
Luminous Unit Co., St. Louis, Mo.
McGraw-Hill Publishing Co., New York, N. Y.
Macbeth-Evans Glass Co., Pittsburgh, Pa.
Millville Electric Light Co., Millville, N. J.
Mutual Lamp Mfg. Co., New York, N. Y.
National Lamp Works of General Electric Co., Nela Park, Cleveland, Ohio.
National X-Ray Reflector Co., Chicago, Ill.
New Bedford Gas & Edison Light Co., New Bedford, Mass.
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New York Edison Co., New York, N. Y.
New York & Queens Electric Light & Power Co., Long Island City, N. Y.
Pennsylvania Power & Light Co., Allentown, Pa.
Peoples Gas Light & Coke Co., Chicago, Ill.
Pettingell-Andrews Co., Boston, Mass.
Philadelphia Electric Co., Philadelphia, Pa.
Philadelphia Electric Manufacturing Co., Philadelphia, Pa.
L. Plaut & Co., New York, N. Y.
Portland Railway, Light & Power Co., Portland, Ore.
Potomac Electric Power Co., Washington, D. C.
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Public Service Corporation of New Jersey, Newark, N. J.
Public Service Company of Northern Illinois, Chicago, Ill.
Reliance Metal Spinning & Stamping Co., Brooklyn, N. Y.
Rochester Gas & Electric Corp., Rochester, N. Y.
Shapiro & Aronson, Inc., New York, N. Y.
Societa Idroelettrica Piemonte, Turin, Italy.
Southern Electric Co., Baltimore, Md.
Sterling Bronze Co., New York, N. Y.
Stone & Webster, Boston, Mass.
Suburban Gas & Electric Co., Revere, Mass.
Tungsten Wire Works, A. B., Stockholm, Sweden.
Union Gas & Electric Co., Cincinnati, Ohio.
United Electric Light & Power Co., New York, N. Y.
United Gas Improvement Co., Philadelphia, Pa.
United States Glass Co., Pittsburgh, Pa.
Alfred Vester Sons, Providence, R. I.
Welsbach Co., Gloucester, N. J.
Welsbach Street Lighting Co., Philadelphia, Pa.
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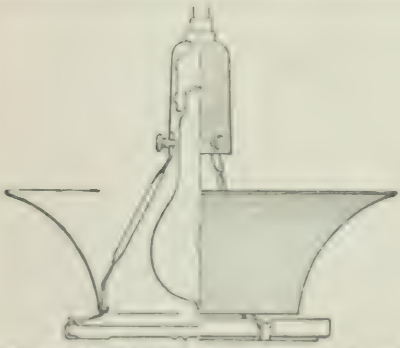

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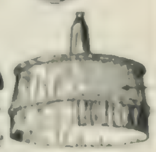

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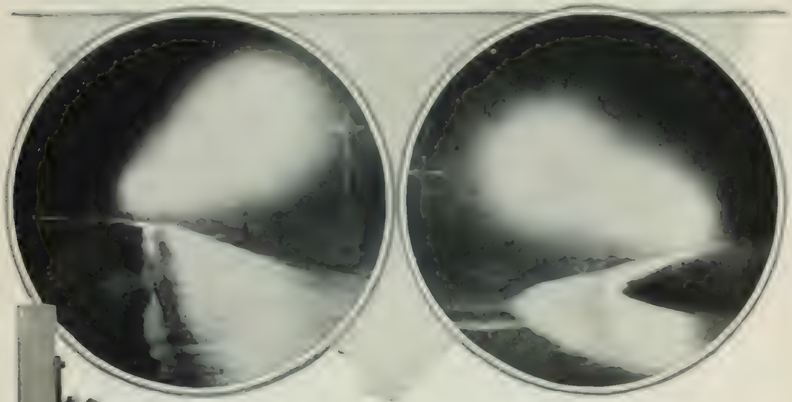

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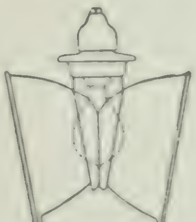

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